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Atlantic City International Airport,
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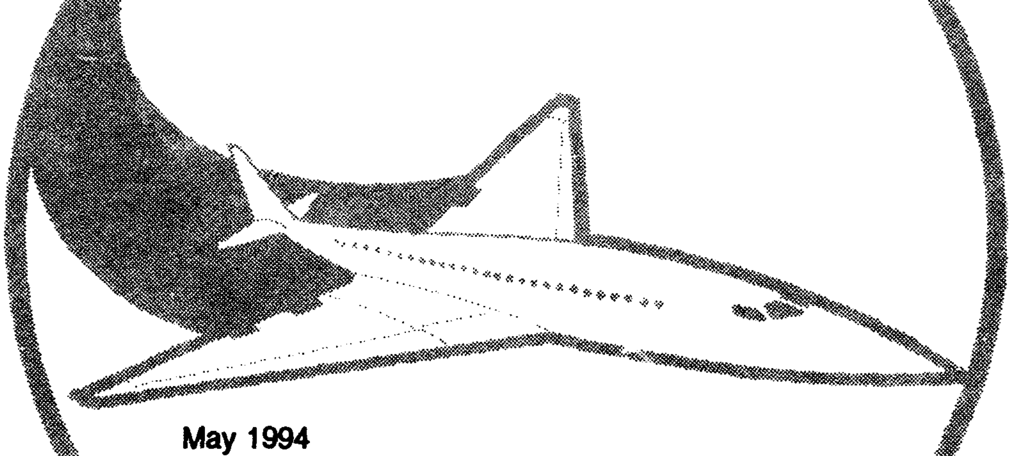
Controller Evaluation of Initial Data Link En Route Air Traffic Control Services: ISSS Design Development Study 1

Air Traffic Data Link Validation Team



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16. Abstract

This report documents the first Federal Aviation Administration (FAA) design development study of an initial group of en route air traffic control (ATC) services designed for transmission by Data Link technologies using the Initial Sector Suite System (ISSS) as an air traffic controller interface. The research was conducted by the FAA Technical Center, Airborne Collision Avoidance and Data Systems Branch, ACD-320.

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Ms. Karen Burcham was the Data Link Program Manager with overall responsibility for the program.

Ms. Barbara Cassada was the Data Link Senior Technical Program Manager responsible for the overall management and development of the Data Link services.

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Mr. Timothy Hancock provided scenario development, airspace and procedures development, and ATC system expertise.

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Mr. George Rowand, CTA, provided voice communication configuration.

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The following Air Traffic Control Specialists, members of the Air Traffic Data Link Validation Team (ATDLVT) and ISSS En route Systems Team (ERST), were active participants in this study.

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) is pursuing an initiative to develop and implement a Data Link system intended to enhance communications between ground-based air traffic control (ATC) and aircraft operating within the National Airspace System (NAS). By providing digital information transfer along with the ability to discretely address individual receivers, Data Link is expected to reduce frequency congestion on existing voice radio communication channels. It will also enhance the safety and productivity of ATC operations.

In order to insure that the introduction of Data Link will result in the greatest possible benefit, the FAA Technical Center is conducting a program of research and development to: (a) guide the design of effective ATC services; (b) evaluate their impact on system performance; and (c) promote optimal integration between the system and its air traffic controller and aircrew users.

Original developmental work focused on designing and testing a group of initial services and functions for the currently operational en route Host computer/Plan View Display (PVD) workstation system. Controller-in-the-loop simulation studies were used to produce refined PVD displays, command inputs, and communications procedures which were used as the basis for preparing a functional specification for Data Link service implementation in the Host computer system. The initial services defined within the specification include altitude assignment, transfer of communication, menu text functions, communication backup, and initial contact.

As part of the Advanced Automation System (AAS) program, a new controller workstation will begin to replace the PVD controller interface over the next several years. This Initial Sector Suite System (ISSS) common console will introduce color coding dimensions, non-dedicated display surfaces, logical displays, keyboard inputs, and a new command language syntax. Because of these changes, empirical research will be needed to produce a Data Link implementation specification which will optimize controller usability by conforming to general Data Link design principles, while being fully integrated with the conventions for user interaction unique to the ISSS design. The overall goal of the study described in this report was to obtain initial controller input to the development of effective ISSS Data Link service designs.

The primary objective of this study was to evaluate the controller interface and procedures associated with candidate designs for initial ISSS Data Link services and functions. The study also was used as an opportunity to address two secondary objectives. Evaluations of system fidelity were obtained to assess the capability of a prototype ISSS simulator to support future development and testing of Data Link services. In addition, test runs were conducted to obtain preliminary estimates of the projected impact of ISSS Data Link on controller capabilities and ATC system performance.

Eight controllers engaged in a series of training exercises, structured design reviews, full scale simulation tests, and formal debriefings to provide evaluative data. Data Link training and full scale simulation testing were performed in the Host/PVD laboratory and in a prototype ISSS simulation facility in order to provide a comparative baseline for evaluation of the candidate ISSS Data Link designs. Identical test scenarios were presented in both simulation environments and were derived from the Oakland Air Route Traffic Control Center (ARTCC).

The design review process revealed a number of deficiencies in the candidate versions of the initial ISSS Data Link ATC service designs, and generated design changes to remediate those deficiencies. Requirements for modifications and enhancements to the candidate service designs included: (1) the development of speed and heading services; (2) the addition of logic checks to prevent inadvertent deletion of open Data Link transactions; (3) modification of the initial contact service to prevent a high incidence of false alarm alerts; and (4) the development of a capability to display a historical record of Data Link transactions that have been successfully completed with an aircraft. In addition, the results indicated that, to facilitate Data Link integration, recommendations should be forwarded to the AAS program to modify current command input specifications.

The participating controllers favorably evaluated the ISSS prototype simulation system as a test bed for continued Data Link service development. Suggested improvements included the addition of a limited number of additional ISSS views and command functions, enhancement of the simulated aircraft models, and the expansion of the system to multiple common console suites.

The findings derived from the full scale simulation phase of the study demonstrated that Data Link significantly reduced occupancy of the voice radio channel by controllers, and that this benefit was achieved with no adverse impact on controller workload. Furthermore, the results indicated that Data Link will increase system safety, and that the combination of ISSS and Data Link will produce a significantly greater positive effect on controller efficiency and productivity than the implementation of either system alone.

It was concluded that two way Data Link services are fully compatible with the ISSS. The results suggest that Data Link will enhance the efficiency of domestic ATC operations by expanding the capacity of the air-ground communications channel. They also indicate that this positive effect will be enhanced by the improved controller interface associated with the ISSS.

Based on the results and conclusions outlined above, as well as others described in this report, it is recommended that the FAA continue development of Data Link ATC services for the ISSS, and that it should integrate these services with the ISSS implementation schedule at the earliest feasible opportunity. Future work with the ISSS should include the modification of the Data Link services as suggested by the study findings, testing with multiple console suites at each sector, and evaluation of Data Link communications functions to be performed by associate controllers.

1. INTRODUCTION.

1.1 PURPOSE.

This document presents the results of a Federal Aviation Administration (FAA) Technical Center investigation of en route air traffic control (ATC) services developed for transmission using Data Link technology. Candidate designs for five ATC services and functions for the new Initial Sector Suite System (ISSS) common console were prepared based upon design specifications originally developed for the currently operational Host computer/Plan View Display (PVD) system, and upon specifications for the ISSS controller interface. The designs were implemented on a prototype ISSS simulation system for review and evaluation by air traffic controllers.

Subject controllers participated in simulated en route airspace test trials to recommend requirements for user interface and procedural design changes and enhancements, and to provide projective assessments regarding the impact of ISSS Data Link on controller capabilities and ATC system performance. The study was the first in a planned series of iterative design development tests which will culminate in the production of functional design specifications for an operational en route ATC Data Link communications system supported by the ISSS.

1.2 BACKGROUND.

1.2.1 ATC Communications Issues.

Maintenance of the safe and efficient flow of air traffic is predicated on the availability of a two-way communications link between ATC facilities and aircraft systems. For the past 50 years, the air-ground link has been provided by simplex radio channels over which air traffic controllers and aircrew exchange voice messages. The voice radio medium has proven its effectiveness. However, current growth in the volume of air traffic and increasing air-ground information transfer requirements are beginning to exceed its inherently limited capacity. As a result, the communications system has begun to place significant constraints on the overall performance of the ATC system.

Because the voice radio link operates in a broadcast mode between a single control position and all aircraft operating in the airspace sector, frequency congestion is a common occurrence when the volume and complexity of air traffic increases. Such saturation of the communications channel affects the performance of the ATC system by preventing the timely issuance of clearances, and by restricting the vital exchange of information upon which safe and efficient operation of the National Airspace System (NAS) depends.

In addition to the limitations that it imposes through frequency congestion, the voice radio channel has been identified as a major contributor to errors in the ATC system. The FAA has noted that as many as 23 percent of all operational errors are caused either directly or indirectly by communications mistakes (New York Times, 1988). Similarly, compilations of voluntary reports provided to the Aviation Safety Reporting System by pilots and controllers have shown that a majority of all potentially hazardous incidents that are filed implicate ineffective verbal information transfer (Billings and Reynard, 1981).

Investigations of the nature of prevalent communications errors demonstrate that they are typically the result of an interaction between the characteristics of the voice radio system and the inherent perceptual and cognitive characteristics of its human users (Shingledecker, 1990). Acoustic confusions, alphanumeric transpositions, misinterpretation due to pronunciation and phraseology problems, poor memory for transient speech presentations of ATC information, and blocking of the radio channel caused by improper keying techniques are common sources of human-induced error found by these studies. In addition, many errors seem to be potentiated by the frequency congestion problem as users experience difficulty in monitoring for relevant messages on the crowded radio channel, and become reluctant to clarify suspected confusions to avoid further congestion.

1.2.2 Data Link Communications.

Data Link is a digital communications technology which is being developed as a supplement to traditional voice radio for two-way, air-ground ATC communications and other applications. As shown in figure 1, Data Link communications can be supported by several transmission media. These include very high frequency (VHF) radio, satellite links, and the Mode Select (Mode S) secondary surveillance radar system. Under current FAA plans, these multiple links will be integrated within a common Aeronautical Telecommunications Network to provide seamless air-ground communications throughout the NAS.

Regardless of the specific method used to create the channel, Data Link communications are distinguished from traditional voice radio links in two essential ways. First, unlike analogue voice messages, Data Link messages consist of digitally coded information. Thus, data may be entered for transmission either manually, or by direct access to information contained in airborne or ground-based computers. Furthermore, the capability of a digital system to provide automatic error checking of sent and received messages makes Data Link a highly reliable system which is not susceptible to degradation by interfering noise sources.

The second way in which Data Link differs from the voice radio channel is its capability to discretely address individual receivers. Unlike the simplex radio system which permits only a single speaker to transmit on the broadcast frequency at any time, Data Link messages can be sent selectively. Furthermore, transmission rates are not artificially bounded by the effective speaking and listening rates of the user. As a result, Data Link channels can have a much higher capacity than voice channels, and critical messages sent by a controller are assured of receipt only by the intended aircraft.

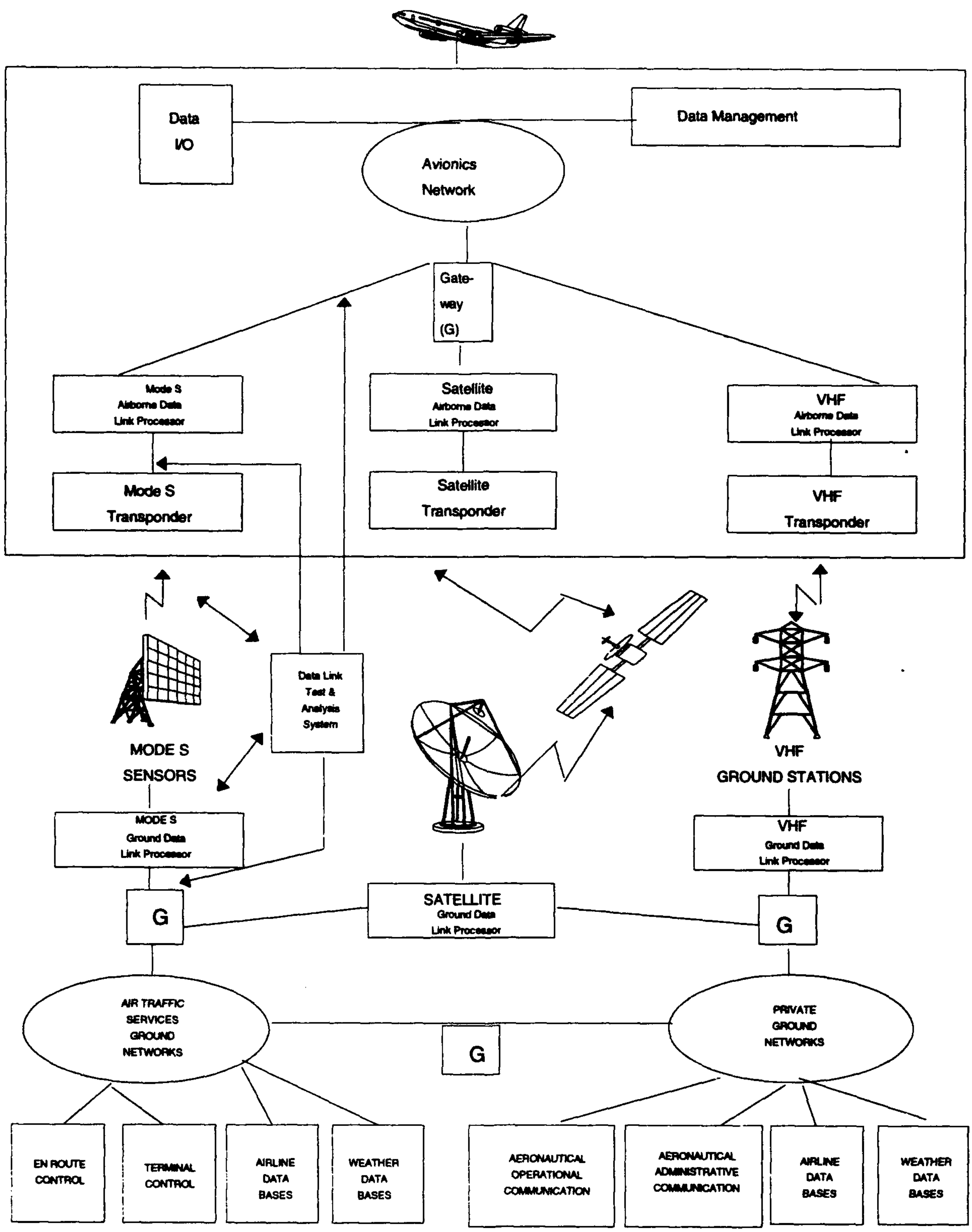

FIGURE 1. PROPOSED DATA LINK SYSTEM

1.2.3 ATC Applications of Data Link.

The development of Data Link communications is a critical element of the FAA's Capital Investment Plan (CIP) to update and enhance ATC technology. In its later phases, the CIP will introduce sophisticated automation systems that will make use of intelligent software and numerous data sources to optimize the flow of traffic. These advanced systems will be capable of optimizing traffic flow, detecting and resolving potential flight path conflicts, providing pilots with preferred routings, and preventing disruptions to overall system operations. A majority of the planned automation innovations will depend upon the reliable, high capacity exchange of information between airborne and ATC computers that will be provided by the Data Link system.

Even before it fulfills its function of enabling end-state system automation, Data Link will provide air traffic controllers and aircrew with a new channel of direct communication which has the potential to produce significant improvements in system safety and productivity. In this role, the unique characteristics of Data Link communications are expected to relieve constraints on efficiency that are attributable to congestion on voice radio frequencies. It will also reduce prevalent communication errors which produce disruptive delays and can compromise flight safety.

Demands on the voice channel should be reduced in proportion to the number of ATC services that are assigned to the Data Link system. In addition, by automating or simplifying pilot and controller functions in the communication process that are subject to error, Data Link should improve the overall effectiveness of information transfer. For example, using Data Link it will be possible to reduce ambiguous message transmissions by storing standard clearances in computer memory for simplified uplink to an aircraft. Likewise, failures to detect messages and accidental acceptance of clearances by unintended aircraft will be eliminated by discrete addressing. Interpretation errors should be reduced by the availability of a persistent and recallable visual display of the received data. Finally, the system will have the ability to automatically verify the integrity of a message without human intervention.

1.2.4 En Route Data Link Controller Research and Development at the FAA Technical Center.

As discussed above, the comparative technical advantages of Data Link, and its ability to supply a second air-ground communication channel, make it a promising candidate for enhancing overall ATC system performance. However, Data Link also will introduce a profound change in the way tasks are accomplished by controllers, and in the way aircrew will receive and respond to ATC instructions. Because of this, the ultimate success of Data Link will be critically dependent on the extent to which it is thoroughly integrated with its human users and with the full range of tasks that they are required to perform.

Recognition of the need to consider operational suitability and human factors issues as primary drivers of the design process prompted the FAA Technical Center to initiate a program of manned simulation research to guide the development of Data Link ATC services. The overall goals of this research are to (1) define useful Data Link services, (2) determine the user information requirements for Data Link communications, (3) develop display formats, data entry methods and procedures which promote efficient controller performance, and (4) evaluate the impact of Data Link services on both human and system performance.

The design of Data Link ATC services began in 1988 at the FAA Technical Center with a series of controller-in-the-loop simulation studies. These studies were aimed at iteratively developing and testing a group of initial services and functions for the currently operational NAS en route Host computer/PVD workstation system. Based upon measures of controller workload, performance, and operational suitability, design development studies produced refined PVD displays, command inputs, and communications procedures. These were used as the basis for preparing a functional specification for Data Link service implementation in the Host computer system (Buck et. al., 1991).

The initial services defined within the specification include altitude assignment, transfer of communication, menu text functions, and communication backup. Host/PVD research conducted subsequent to the publication of the initial specification also produced a capability to receive an initial contact message from Data Link-equipped aircraft following the transfer of communication.

1.3 DATA LINK FOR ISSS.

As part of the Advanced Automation System (AAS) program, a new controller workstation will be introduced into the en route ATC environment within the next few years. With the evolution of the AAS, this ISSS common console will eventually replace all Host/PVD controller interfaces. During the first phase of the transition process, the common console will be supported by the same Host computer that supports the current PVD workstation and will, as a minimal requirement, provide functional capabilities that are equivalent to the existing system.

This shared functionality and computer support for the common console and PVD are expected to make many of the design specifications that were developed from PVD research findings directly applicable to the implementation of initial Data Link services for the ISSS. However, the ISSS will introduce new display color coding dimensions, non-dedicated display surfaces, logical displays, keyboard inputs, and a new command language syntax. These changes would accommodate a number of candidate implementations under the general design specification. Thus, additional empirical research will be needed to develop an implementation specification for the ISSS that will insure optimal controller usability. Such a specification must embody the general Data Link human factors design priniciples discovered in earlier research, while being fully integrated with the conventions for user interaction unique to the ISSS. The primary purpose of the study described in this report was to obtain initial controller input to the development of effective ISSS Data Link service designs.

1.4 INITIAL EN ROUTE ISSS DATA LINK SERVICES.

In order to provide a baseline for the development of ISSS Data Link, the FAA generated a set of candidate designs for an initial set of ATC services and functions. These designs for controller displays, command inputs and ATC computer automation functions were based on requirements originally developed for the Host/PVD system, and on controller interface and interaction specifications published for the ISSS.

Detailed descriptions of the baseline candidate designs that were evaluated in this study are presented in appendix A. The general functions performed by the services, and brief descriptions of how they are provided using Data Link, are presented below:

a. Transfer of Communication (TOC). TOC is the message sent to an aircraft after track control has been passed to a new sector instructing the pilot to change radio frequencies. Using the candidate Data Link service, this message is automatically prepared b ATC computer and uplinked to the pilot either automatically when track control is accepted, n a controller input action.

b. Initial Contact (IC). When an aircraft receives a new radio frequency, current ATC procedures require the pilot to contact the new controller and, in many cases, to report the aircraft's currently assigned altitude. With the candidate Data Link version of IC tested in this study, the aircraft (pilot or airborne automation) appends its assigned altitude to th wilco response for the TOC message. Upon receipt, the altitude is automatically compared to the assigned altitude in the NAS data base. An alert is presented to the receiving controller if the aircraft fails to downlink the altitude, or if the downlinked altitude and data base altitude do not match.

c. Altitude Assignment (AA). Using the candidate ISSS Data Link design, the controller can uplink an assigned altitude or an interim altitude through keyboard command actions specifying the intended aircraft (one or more) and the altitude value. Receipt of the pilot wilco automatically updates the appropriate Full Data Block (FDB) on the controller's situation display and, for assigned altitudes, the NAS data base.

d. Menu Text (MT). MT is a Data Link function which permits the controller to select and uplink a commonly used message from a menu view. In the present study, the menu contained altitude, speed and heading clearances as well as non-control text messages.

e. Communications Backup (CB) (Free Text). CB provides the controller with an ability to compose and uplink an unformatted (free text) message using keyboard inputs.

The candidate services were designed using accepted ISSS display and command conventions. The MT menu and the Data Link Status List, used to provide information on the content of open transactions and their status were implemented as ISSS views (logical displays). Data Link inputs conformed to the ISSS command syntax, and were displayed in the ISSS Message Composition (MC) view. Symbology was added to the first line of the FDB to provide a Data Link equipage and eligibility indicator, and additional FDB modifications were made to provide message status, content and alert displays for some of the services.

1.5 ORGANIZATION OF THE REPORT.

The following sections of this report present the research methodology that was used and the findings that were obtained in the first FAA Technical Center controller evaluation of en route Data Link ATC services for the ISSS. Section 2 describes the specific objectives of the study and the testing approach that was used to achieve these objectives. Section 3 presents the results of the testing. Sections 4 and 5 list the conclusions that were derived from the results and offer recommendations for future development of an operational ISSS Data Link capability.

2. TEST DESCRIPTION.

2.1 OBJECTIVES.

This study was conducted to achieve the following primary objectives, in pursuit of the goal to develop initial Data Link services and procedures for the ISSS:

a. Evaluate the usability and operational suitability of the controller interface, and procedures associated with candidate designs for initial ISSS Data Link services and functions.

b. Provide design guidance for correcting any detected problems with the candidate controller interface, and for enhancing the services.

c. Evaluate the capability of a prototype ISSS simulation system to support future development and testing of Data Link services.

d. Obtain preliminary estimates of the projected impact of ISSS Data Link on controller capabilities and ATC system performance.

2.2 TEST APPROACH.

Unique expertise in the design of en route Data Link ATC services and in the operation of the ISSS resides in two separate teams of air traffic controllers. The teams have been appointed by the FAA to represent operational concerns in the development of these new ATC systems. Members of the En Route Systems Team (ERST) have been actively involved in the evolution of the common console hardware, display requirements and ISSS procedures. Beyond acting as overseers of this effort, these team members have the highest available level of controller familiarity with ISSS design conventions, common console operation, and procedural concepts for the future ISSS-based en route ATC environment.

Members of the Air Traffic Data Link Validation Team (ATDLVT) directly participated in the design of the initial en route Data Link services for the Host/PVD, and were closely involved with the evaluation exercises conducted in the Data Link test bed. Thus, these controllers are thoroughly versed in the design philosophy underlying Data Link ATC services, as well as the use of the system under various simulated air traffic scenarios.

The present study drew upon the expertise from these two teams, as well as the members' shared operational experience in en route ATC by recruiting members from both teams to participate in the evaluation of the candidate ISSS Data Link implementation. These controllers engaged in a series of training exercises, structured design reviews, full scale simulation tests, and formal debriefings to provide evaluative data. Data Link training and full scale simulation were performed both in the Host/PVD laboratory and in the prototype simulation facility to provide a comparative baseline for evaluation of the candidate ISSS Data Link designs. Identical test scenarios were presented in both simulation environments, and were derived from the Oakland Air Route Traffic Control Center (ARTCC) using four airspace sectors with arrival and departure traffic from the San Francisco International Airport (SFO).

To ensure that controller evaluations were based on accurate knowledge of the current Host/PVD Data Link and ISSS designs, the first phase of this study was devoted to classroom training and practice. This included instruction on the PVD Data Link service designs, the ISSS candidate Data Link service designs, and general operation of the ISSS common console.

In the second phase of the study, all of the subject controllers participated in a systematic evaluation of the candidate ISSS service designs. For each candidate service, this design review activity required the controllers to examine precise descriptions of inputs and displays, perform correlated design test exercises in the prototype ISSS simulator, and complete a detailed evaluation booklet.

In the final phase of the study, the controllers participated in full scale simulation exercises. These test runs were conducted to provide the experience needed to assess the overall effectiveness and acceptability of the candidate ISSS Data Link designs. They also presented a basis for making projective judgments regarding the impact of Data Link under an actual operational implementation.

2.3 TEST CONDUCT.

2.3.1 Subjects.

The subjects for this study were eight Full Performance Level (FPL) ATC specialists who were proficient in ARTCC radar control operations. Six of these controllers were recruited from the ATDLVT and had participated in the conceptual development and testing of Data Link services for the Host/PVD system. The remaining two subjects were recruited from the ERST. Both had participated in ISSS controller interface reviews on that team, and on the earlier Sector Suite Requirements Validation Team (SSRVT) during original ISSS design deliberations.

2.3.2 Test Facilities, Test Scenarios, and Data Link Transaction Times.

The study was conducted in two laboratories located at the FAA Technical Center. Training and testing on the Host/PVD Data Link services were performed in the en route portion of the Data Link test bed. Pseudopilots operating the dynamic simulation (DYSIM) function controlled aircraft targets, and conducted air-ground voice and data communications with the subject controllers. The Host/PVD simulation system in the Data Link test bed provided all current NAS en route functions and displays, and supported all initial Data Link services developed for that system in earlier studies.

Training and testing on the ISSS common console were conducted using the ISSS prototype simulation facility and associated pseudopilot capabilities. The ISSS prototype is an ATC simulator which includes four common console replicas. The replicas use actual ISSS keyboards, trackballs, and cathode ray tube color displays. The prototype software, as implemented for this study, supported the primary command inputs and logical displays specified in ISSS specification documents, as well as the candidate versions of ISSS initial Data Link services. In addition, the software provided the ability to dynamically simulate prepared air traffic scenarios, and to alter aircraft movement in response to pseudopilot inputs.

Four sectors of adjacent en route airspace were simulated on the Host/PVD and ISSS prototype systems. Scenarios developed for both systems used the Oakland ARTCC adaptation and identical airspace sectors. The Oakland ARTCC adaptation was chosen for this study to permit later addition of the Bay Terminal Radar Approach Control (TRACON) and Oakland Oceanic operations. Future simulation studies using this expanded configuration will examine Data Link functionality in multiple ATC environments.

Figure 2 presents a simplified map of the test airspace, along with the primary arrival and departure traffic flows in the four sectors. Traffic patterns used in the scenarios were extracted from Oakland ARTCC System Analysis and Recording (SAR) tapes. Traffic percentage volumes were based on actual Oakland ARTCC Operationally Acceptable Level of Traffic (OALT) values taken from the Traffic Management System data base. All of the sectors worked both arriving and departing aircraft from the SFO, along with a small number of overflights. The majority of the traffic was composed of air carrier jets, with a smaller number of turbo props and military aircraft.

The subjects controlled aircraft in accordance with the provided interfacility Letter of Agreement (LOA) and Sector Standard Operating Procedures (SOPS). All arrival aircraft were required to meet specific in-trail altitude, speed and routing restrictions prior to the hand-off to Bay TRACON. All departure traffic transitioned into Oakland Center airspace on course, climbing to altitudes specified in the LOA.

Several changes to the actual airspace were made to reduce airspace training requirements for this study. The airspace was modified to remove shelved portions of some sectors so that sectors 41, 24 and 12 controlled airspace from the surface to FL230, exclusive of Bay TRACON airspace 14,000 feet and below. Sector 35 owned all airspace from the surface up. In addition, unnecessary intersections, airways, jet routes, navigation aids, and unused airports were removed from the maps to further simplify the problem. Finally, the LOA and SOPS were rewritten to allow operation of the sectors with minimal coordination. This change permitted the single radar controller position, provided by the simulation facilities, to operate the sector without assistance from a Data (manual) controller.

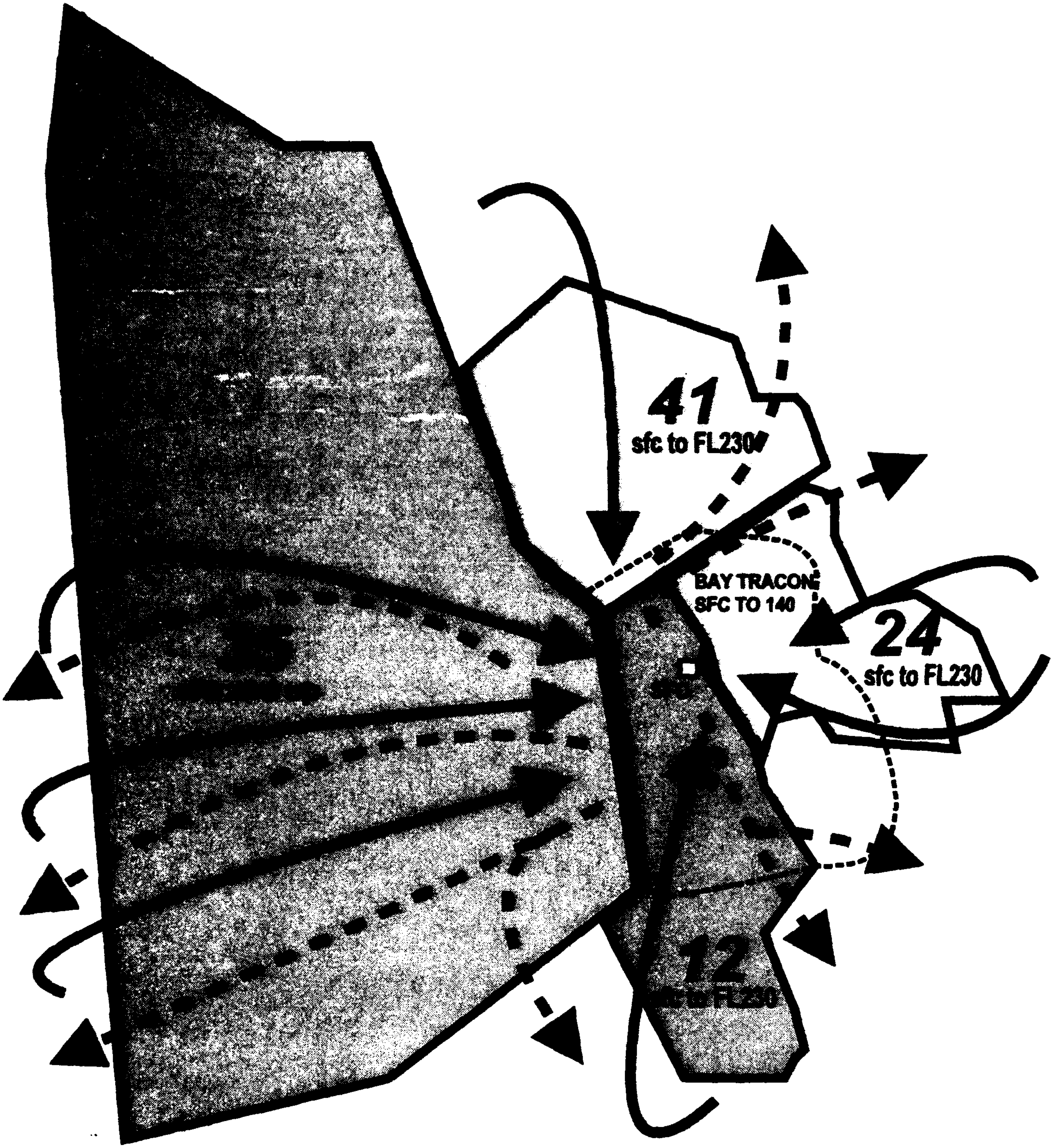

FIGURE 2. OAKLAND ARTCC TEST AIRSPACE

A common distribution of total transaction times was enforced during all training and test simulation trials in which Data Link communications were employed. Total transaction time was defined as the time interval beginning with the controller's data entry initiating an uplink and ending with the receipt of a pilot response. These were randomly drawn from a rectangular distribution representing nominal uplink and downlink transmission times, plus a pilot response delay. The mean of the distribution was 18 seconds with a range of 12 to 24 seconds.

2.3.3 Test Procedures and Data Collection.

2.3.3.1 Training.

One week prior to the study, all subjects received an airspace training package (appendix B), along with a brief description of the study goals and methodology. The subjects were asked to study the airspace before arriving at the FAA Technical Center.

Upon arrival, each of the eight subjects was assigned to one of the four sectors in the Oakland ARTCC, with two subjects per position. In order to maximize airspace familiarity and focus on Data Link operations, these assignments were maintained for all training and subsequent testing.

Preparations for data collection began by providing all subjects with instruction and training on the general operation of the prototype ISSS common console, and on the Host/PVD and ISSS implementations of the initial Data Link services. Formal training was conducted over a period of 3 days in three stages.

In the first stage, the subjects received a 1-hour briefing on the Oakland ARTCC airspace, followed by a 1-hour classroom session explaining and illustrating all Host/PVD Data Link command inputs, displays, and procedures. This was followed by 4 hours of hands-on practice in the Host/PVD Data Link test bed. During this laboratory session, the two subjects assigned to each PVD practiced Data Link operation in scenarios which increased in traffic volume from 50 to 75 percent of airspace capacity after approximately 2 hours. All aircraft in the scenario were Data Link equipped to maximize training efficiency. The paired subjects alternated between observing and actively controlling traffic. The practice session was followed by a 30- minute group session to address Host/PVD Data Link and airspace questions.

The second stage of training introduced the subjects to general operation of the ISSS common console. This training began with 1 hour of classroom instruction on the ISSS command language and syntax, logical displays, and keyboard layout. ISSS functions not supported by the prototype were identified. The candidate Data Link services were not introduced during this briefing. Classroom instruction was followed by a 4-hour practice session in the ISSS simulation facility. Air traffic scenarios, with volumes increasing from 50 to 75 percent of airspace capacity and approximately identical to those used in the Host/PVD training, were presented to permit the subjects to exercise the ISSS functions. During this stage of training, all communications were conducted using voice radio. Subjects worked in pairs, alternating as described in the Host/PVD training protocol. The practice session was followed by a 30-minute question and answer period.

The final stage of training provided subjects with instruction on the candidate initial Data Link services developed for the ISSS common console. A 1-hour classroom session was used to brief the subjects on Data Link inputs and displays, followed by 4 hours of practice in the ISSS prototype facility. The hands-on training followed the same protocol as that used in the first two training stages and used identical airspace scenarios. All aircraft were Data Link equipped.

2.3.3.2 Prototype Evaluation.

After the subjects had finished ISSS training, they completed a questionnaire and participated in a debriefing designed to provide an assessment of the quality of simulation provided by the ISSS prototype system. While the subjects differed greatly in their prior experience with actual ISSS hardware and operations, they were all asked to evaluate the overall fidelity of simulation provided by the system, the operational realism of the system's performance, and the degree to which the prototype emulated the "look and feel" of the actual ISSS common console. The controllers were asked to judge these qualities in relation to simulation requirements for developing and testing Data Link functions, rather than against an absolute criterion of perfect ISSS emulation. Debriefing discussions centered on identifying needed improvements to the ISSS prototype simulation system for future Data Link studies. Appendix C includes a copy of the questionnaire used in the prototype evaluation.

2.3.3.3 ISSS Data Link Design Review.

Evaluation of ISSS Data Link began on the fourth day of the study with a formal, structured review of the candidate ISSS service designs. The eight subjects completed the design review while seated in two-controller teams at the prototype common console workstations, and controlling aircraft in a series of brief scripted scenarios. Each of these scenarios or frames was designed to permit the controllers to exercise one of the initial candidate service designs, or a group of related design features common to all the services.

Evaluations were made by completing sections of a design review questionnaire booklet which were correlated with the individual scenario frames. The paired subjects worked together in exercising and examining each service and design feature. However, they were instructed to answer evaluation questions individually.

The design review scenario software operated independently on individual prototype workstations, so that the evaluations could be flexibly paced by each pair of controllers. Subjects working at a console were allowed to take as much time as required to complete each booklet section, and to repeat the associated scenario frame if necessary before moving on to the next section. In cases where a service would normally require cooperation with an adjacent sector (e.g., TOC), the simulation software was modified for the design review to emulate these inputs. Test facilitators were available to assist the subjects in exercising the services, and to answer any questions regarding inputs or displays.

The design review was organized into the following sections: (1) Status List, Data Block Displays, and Entry Error Messages; (2) TOC; (3) AA; (4) IC; (5) MT; and (6) CB. For each section, the subjects were instructed to first read the description of the design provided in a separate booklet (see appendix A). They then completed a scripted set of activities interacting with the associated scenario frame. Finally, they completed the correlated questionnaire items before proceeding to the next section.

Initial questionnaire items in each section of the design review verified the fidelity of the service implementations by requiring the subjects to judge the correspondence between the descriptions and their actual experience with the ISSS prototype. Succeeding items assessed the acceptability of the service implementations observed in the simulations, and solicited recommendations for desirable and required design modifications. The design exercises and correlated questionnaire items are included in appendix C.

Upon completion of the review exercise, all subjects met with test personnel for a group debriefing session. This 4-hour session was used to perform an item-by-item examination of the subjects' responses to the review questionnaire. The emphasis of the debriefing was to: (1) identify and resolve disagreements regarding the fidelity and acceptability of the service designs and; (2) achieve a consensus regarding recommended changes to the service designs. Designated test personnel recorded detailed notes on the issues, resolutions and design modifications discussed during the debriefing. In addition, a complete audio tape record was maintained for future reference during data analysis.

2.3.3.4 Full Scale Simulation.

On the fifth and sixth days of the study, the subjects participated in a series of full scale simulation tests. The purpose of these test runs was to provide the subjects with a realistic simulation experience as a basis for expert comparative evaluation of the workload, operational utility, and acceptability of the ISSS Data Link services, as implemented for this study.

During the full scale simulation runs, controllers operated in test scenarios with air traffic at 100 percent of airspace capacity. They were required to control traffic in the ISSS prototype under voice radio-only, and under radio plus Data Link communication conditions. To provide a comparative baseline, the subjects also were tested under voice-only and radio plus Data Link conditions in the Host/PVD Data Link test bed. In Data Link conditions, 80 percent of the aircraft were equipped for both Data Link and voice radio communication, while the remaining 20 percent were able to communicate only via voice radio.

To minimize the effects of airspace learning on controller assessments, two equivalent 50-minute scenarios were used for these test runs. These scenarios involved similar traffic patterns and equal numbers of aircraft, but differed slightly in aircraft sequence and spacing.

The experimental design for the full scale simulation testing is illustrated in table 1. The eight subjects were divided into two groups. Because testing time in the Host/PVD Data Link test bed was available only in the late afternoon, the experimental design was configured so that ISSS testing sessions preceded Host/PVD testing sessions on each of the two full scale simulation days. However, as

TABLE 1. FULL SCALE SIMULATION EXPERIMENTAL DESIGN

Session

	1	*2*	*3*	*4*
	Group 1		*Group 2*	
Day 1	*ISSS* *VOICE* *Scenario A*	*ISSS* *DATA LINK* *Scenario B*	*PVD* *DATA LINK* *Scenario A*	*PVD* *VOICE* *Scenario B*

	5	*6*	*7*	*8*
	Group 2		*Group 1*	
Day 2	*ISSS* *DATA LINK* *Scenario A*	*ISSS* *VOICE* *Scenario B*	*PVD* *VOICE* *Scenario A*	*PVD* *DATA LINK* *Scenario B*

shown in the table, the two groups alternated between testing in the Host/PVD Data Link test bed and in the ISSS facility. This alternation counterbalanced for order of testing on the two Data Link implementations, and minimized transfers between the two laboratory facilities. The air traffic scenarios were partially counterbalanced with the independent variables such that both scenarios were used under Data Link and voice conditions with both system implementations.

As an auxiliary control over learning effects in the experimental design, all subjects participated in warm-up trials in both the ISSS and Host/PVD test facilities. These warm-up runs were completed on the day before the beginning of testing and consisted of abbreviated versions of the Data Link test scenarios using 100 percent traffic loads and 80 percent Data Link equipage.

Data were collected on radio usage to obtain an index of the extent to which Data Link was used by the subjects to substitute for voice communications during the ISSS test trials. As subjects performed in the ISSS test runs, simulation computers recorded the number of voice messages sent by each controller and the duration of each voice message. For the purpose of this measurement, a voice message was defined as a microphone push to talk (PTT) action followed by a release action.

The primary data that were obtained during full scale simulation testing were based upon expert judgments provided by the controller subjects. These data were collected using quantified rating techniques, questionnaires administered after each test session, and questionnaires administered after all of the test sessions were completed.

At the termination of each test run, each controller provided an overall rating of the workload they experienced during the scenario using the Subjective Workload Assessment Technique (SWAT). SWAT was developed in the early 1980's by the U.S. Air Force as a standardized method for obtaining quantified estimates of perceived workload in a broad variety of occupational tasks. The technique has received extensive use in simulation and operational testing environments within the Department of Defense, and was used successfully with air traffic controllers in prior en route and terminal Data Link studies.

SWAT is used to rate the level of workload experienced by a subject during a preceding period of work. Briefly, SWAT consists of three, three-point rating scales referring to the dimensions of time load, mental effort, and psychological stress. Subjects indicate the workload associated with an activity by marking the appropriate point on each scale.

A unique feature of this workload measurement technique is that the three ordinal ratings that are obtained are converted to single points on an overall interval measurement scale. The conversion uses a mathematical analysis method known as conjoint measurement which produces values ranging from 0 (low workload) to 100 (high workload). This method not only yields data which are amenable to parametric statistical testing, but also tailors the measurement scale to each individual's (or homogeneous group's) concept of how the time, effort and stress dimensions combine to produce the overall perception of workload.

The interval scale used to interpret the ordinal ratings is created by having subjects generate an ordering of all 27 combinations of the time, effort, and stress levels on the scales. This ordering reflects their individual concepts of how the three dimensions combine to produce different workload levels. The card sorting task used during the scale development exercise was completed by all eight subjects in this study during a prebriefing session. The SWAT rating scale is included in appendix C along with instructions provided to subjects during the scale development exercise.

After completing a SWAT rating the subjects also were asked to note any factors which contributed to the workload perceived during the run. On Data Link trials they were prompted to comment on any operational problems that they experienced which were associated specifically with using the Data Link services.

2.3.3.5 Post Test Evaluations.

After finishing all four test runs, the subjects completed two sets of ratings. These ratings were designed to obtain projective estimates of Data Link impact on controller and system performance, and to generate a summary evaluation of each of the candidate ISSS Data Link service designs.

In the first set of ratings, the subjects were asked to estimate the way in which the introduction of Data Link and ISSS would impact general ATC performance in an actual operational implementation.

These ratings were designed to separate the effects of general differences between the Host/PVD and ISSS common console systems from those of the two Data Link implementations. A sample of the rating form used to obtain the projective judgments is presented in appendix C.

Projective estimates were solicited for each of four factors: (1) controller workload; (2) controller efficiency/productivity; (3) system capacity; and (4) system safety. For each factor, the respondents made all six comparisons between pairs of the four test conditions:

Host/PVD - voice
Host/PVD - voice and Data Link
ISSS - voice
ISSS - voice and Data Link

In each comparison, they could rate the two members of the pair as equal on the factor (e.g., workload), or judge either of the two as "somewhat" or "much higher" on that dimension. The resulting data were transformed by using the Analytical Hierarchy Process (AHP) (Saaty, 1980) to produce ratio scale values for each test condition.

In the second set of post test ratings the controllers evaluated each of the five service designs on two factors (see forms in appendix C.). The first scale required the subjects to assess the operational effectiveness and suitability of the service design. The data form permitted the subject to rate a service as "not operationally suitable," or on a 7-point scale ranging from 1 "minimally effective" to 7 "highly effective." Instructions for completing this scale asked the subjects to use their experience in the Data Link Test Bed and their prior background in en route ATC operations to assess how well each service design could accomplish its intended task in the full range of potential field environments.

The second rating was an estimate of the acceptability and preferability of each of the service designs to air traffic controllers. The data form permitted the subjects to rate a service as "completely unacceptable," or on a 7-point scale ranging from 1 "acceptable, but not preferred" to 7 "highly preferred." Instructions directed the subjects to consider the extent to which the displays, input requirements, and procedures used to deliver a service would be useable by air traffic controllers.

Additional explicit instructions for these two scales indicated that the dimensions of effectiveness and preference should be treated independently, since a service might include all functions needed to meet operational requirements and still be poorly suited to the way in which controllers perform their functions. Likewise, a design could be easy to use, but have missing features which prevent it from meeting operational needs.

2.3.3.6 Final Debriefing.

A final debriefing followed the full scale simulation testing. This debriefing revisited the design of the candidate ISSS services to solicit any additional recommendations regarding changes. The debriefing also was used as a forum for the subject controllers to discuss issues in the development of Data Link and to express any final comments or concerns regarding the general operational impact of implementing Data Link ATC services in the NAS.

3. TEST RESULTS.

3.1 ISSS PROTOTYPE SIMULATION SYSTEM EVALUATION.

One of the objectives of this first study of ISSS Data Link ATC services was to validate the fidelity of the system used to exercise the candidate service designs within the context of dynamic ATC simulations. Unlike earlier en route studies in which simulations were carried out on operational PVD workstations, development of Data Link for the pre-operational ISSS required the use of prototype hardware and software which were not designed to be a precise copy of the actual system, or to provide all of its functionality. Thus, it was necessary to ensure that the prototype faithfully reproduced those aspects of the ISSS that may affect controllers' Data Link performance or the judgments they would be asked to make about Data Link during simulation testing. To evaluate that capability, the subjects in this study completed a questionnaire and participated in a group discussion after completion of the training and practice sessions.

The overall response to the prototype system was very favorable, and subjects with the highest level of ISSS experience noted that its capabilities were in many ways superior to equipment and software that they had worked with during ISSS design evaluations. Detailed results are discussed in the following subsections.

3.1.1 Prototype Hardware.

When asked to assess the realism of the prototype hardware including the common console design, input devices, display surface and audio communications system, all eight subjects agreed that the prototype provided sufficient realism to support Data Link development. Individual comments included one recommendation that a foot pedal microphone switch be added for the audio communications system. In addition, two controllers from the ATDLVT noted that the unconventional layout of the numeric entry pad on the keyboard made it difficult to use. However, it should be noted that the keyboards were actual ISSS units. Thus, these criticisms were not relevant to evaluation of the prototype system's fidelity.

3.1.2 Screen Graphics and Text.

All of the subject controllers rated the appearance of the screen graphics and text as sufficiently realistic. This unanimous opinion included the fidelity of color coding, view design, and all other visual representations.

3.1.3 Dynamic Aspects.

The controllers also were asked to assess the realism of the dynamic aspects of the prototype simulator in terms of system response time to controller inputs and the movement of aircraft tracks on the situation display. While five of the subjects rated the prototype as being sufficiently realistic, the remaining three subjects indicated that aircraft maneuvering characteristics were noticeably different from those observed in actual operational conditions.

Subsequent group discussion of this criticism suggested that, while the realism of aircraft movement in the prototype was equivalent to that provided by the DYSIM training function used in operational ARTCC's, higher fidelity in the prototype system would be desirable. Further examination of simulation characteristics that would improve dynamics indicated that changes in aircraft performance models and in the pseudopilot interface would be desirable.

Several subjects noted that the pseudopilots were sometimes unable to keep pace with entering aircraft clearances to the workstation in response to controller commands. For the present study, this problem was solved before subsequent full scale simulation exercises by adding a second operator to each pseudopilot workstation. However, it was recommended that a long term solution will require an analysis of potential workstation interface modifications to ease data entry.

The controllers also suggested that capabilities be added to the pseudopilot workstations to permit more realistic aircraft responses to clearances involving a crossing restriction with a speed stipulation. Because the simulation system did not provide a display of the aircraft's position with respect to the fix location, the pseudopilots were forced to reduce speeds immediately upon receiving the message. The controllers indicated that this resulted in an unrealistic situation since actual pilots would initiate the speed reduction much closer to the fix.

Improvements to the computerized aircraft models also were suggested by the subjects to more closely approximate actual aircraft changes in speeds, climb and descent rates, and turn rates. The test controllers felt that these tended to occur too quickly in the simulation, and that more variability in profiles attributable to aircraft types and company procedures would make controller workload levels more realistic.

3.1.4 Views, Functions and Command Inputs.

Six of the eight subjects indicated that the ISSS functions and views made available by the ISSS prototype in this study were sufficiently realistic and adequate to support future Data Link testing. However, one controller from the ERST, and one controller from the ATDLVT (who had comparatively more prior ISSS experience than other team members) suggested additions. These included:

a. Presentation of the fourth line of the FDB as defined for the ISSS;

b. Addition of the "halo" function used as a callable visual aid for maintaining aircraft separation;

c. The ISSS message recall command permitting display of the last message entered in the message composition (MC) view;

d. The ISSS view expand/contract and enlarge/reduce functions;

e. The ISSS view which presents current vector length, range and leader line length settings; and

f. Activation of the keyboard filter keys, especially the map filters.

A final important change for future Data Link simulations that was discussed during the debriefing was the addition of console positions for the "D" and "T" controllers. ERST members noted that current concepts of operation for the ISSS call for these controllers to play new roles which do not exist in the Host/PVD environment, and which are likely to affect Data Link use and assignment of responsibilities. In particular, the assistant controllers will be increasingly involved with the monitoring and manipulation of electronic flight strips and flight data entries unique to the ISSS. Such changes are expected to affect the overall responsibilities and tasking in en route ATC which could affect the results of future Data Link testing. They were also seen by these controllers as opportunities to integrate Data Link activities with the new task assignments and display opportunities associated with ISSS.

3.2 ISSS CANDIDATE DATA LINK SERVICE DESIGN REVIEW.

The chief goals of this study were to evaluate the candidate designs for initial ISSS Data Link ATC services and to obtain recommendations for enhancements of the human-computer interface and procedures. Data collected in pursuit of these goals were obtained primarily from the design review exercise, and secondarily from summary evaluations of operational suitability and controller acceptance (see section 3.3).

The following subsections present data obtained from the individual design review booklets and from the subsequent debriefing sessions.

3.2.1 Message Status Displays and Entry Error Messages.

Prior FAA Technical Center research conducted for both the en route Host/PVD and the terminal Automated Radar Terminal System (ARTS) IIIA systems, has clearly shown that controllers require feedback on message content and information about message status during an ongoing Data Link transaction. In service designs developed and tested for both of these ATC environments, this information is presented in a status list, and in some instances, in the FDB. Additionally, both designs use a set of graphic symbols displayed in the first line of the FDB to indicate an aircraft's Data Link equipage, and the eligibility of the control position to communicate with the aircraft via Data Link.

The candidate service designs for the ISSS were developed in accordance with these general design principles, including a Data Link status list view, FDB status and content displays for altitude clearances and TOC modeled after the Host/PVD design, and graphic symbology for Data Link equipage/eligibility. Individual design review responses to the design of the status list view and the FDB displays are discussed below in conjunction with relevant group debriefing results.

3.2.1.1 Status List.

All eight subjects indicated that the status list is a necessary feature of the Data Link design. The primary reasons cited for this requirement were that the status list was used for some transactions that provided no FDB display, and that it was used in the design as the sole means for uplinking a "held" TOC message by slewing the cursor to the appropriate list entry. However, some of the subject controllers noted that even if these functions could be handled in other ways, the status list had additional desirable attributes that justified its inclusion in the design. In particular, two subjects indicated that it would serve as a coordination display for "D" and "T" control positions. Three others noted that it acts as a valuable backup to abbreviated FDB status displays by providing more persistent wilco status information, more complete message content information, and a "message sent" indication that can be placed in close proximity to the MC view to act as immediate feedback when uplink commands are typed.

All of the subjects also concurred that the status message abbreviations, service type abbreviations and yellow alert codes used in the status list design were acceptable. One subject expressed a desire to improve alert coding of a message that had received an unable or standby response, or had timed out. Subsequent group discussion produced a recommendation that the entire line of the transaction be displayed in yellow rather than just the UNA, STB, or TIM status abbreviation. The subjects also concurred that the standard ISSS view commands used to move, suppress, and recover the status list view were appropriate and easy to perform.

The subjects were in agreement that the status list should be a secondary display of message status and content which is normally more detailed than the FDB display. In order to permit controllers to tailor the display to individual needs and to reduce clutter, the group recommended that functions be added to provide selective suppression by service/message type and to control the duration of the wilco status display by control position. In addition, the page/scroll commands available in other ISSS views were suggested as valuable improvements.

3.2.1.2 FDB Displays.

The candidate design used a graphic symbol in the first position of the first line of the FDB as an equipage/eligibility display. An open diamond indicated the existence of a Data Link connection between the aircraft and ground system. A filled diamond indicated that the connection existed, and that the viewing control position was eligible to communicate with the aircraft. One of the subjects initially noted that the diamond-shaped symbols might be confused with an aircraft position symbol on the situation display. However, the group consensus was that these codes should be retained. The group also recommended that inquiries be initiated to insure that the filled diamond symbol will be available for use in the actual ISSS.

Significantly, the full group recommended that status and content information be included in the FDB for all control messages. A detailed discussion of this finding is presented in section 3.2.5.1.

3.2.1.3 Entry Error Messages.

Specialized messages were developed for the candidate ISSS services to denote data entry errors specific to Data Link functions. In accordance with ISSS conventions, these error messages were displayed in the MC view when an attempt was made to enter a faulty message, and a special keyboard input was required to delete the faulty message and the error message prior to retyping.

Four of the subjects indicated that the phrasing and display of the error messages were acceptable. However, the remaining controllers suggested changes. Two felt that a more salient indication was needed to emphasize that a Data Link message had not been sent because of an entry error. Both noted that some type of FDB alert would serve this function. Two controllers also expressed a desire to shorten or reword some of the error messages.

During group debriefing, a unanimous position was adopted regarding a change to the entry used to clear an error message. This keyboard input is required in ISSS specifications, presumably to allow for the editing of faulty messages in the MC view as an option to retyping. The controllers participating in the present study felt that brief Data Link messages will not be edited, and that requiring the clear entry before retyping will produce an unacceptable increase in data entry time.

3.2.2 TOC.

3.2.2.1 Mode Indicator.

The candidate design for TOC permitted the controllers to operate this service in either an automatic or manual mode. In the automatic mode, the message containing the new frequency was uplinked when the receiving control position accepted the sector hand off. In the manual mode, the message was held as an item in the status list until the controller initiated the uplink by making a slew entry to designate the item. The controller selected the desired mode by a keyboard entry.

While this general design was acceptable to all of the controllers, they also agreed on the need for an additional display to provide a continuous indication of the active TOC mode. The group concurred that the most acceptable location for this display would be the header area of the status list view. However, it was noted that unless the status list is defined as a view which must be displayed at all times, the mode indication would not be available if the controller chose to suppress this view.

3.2.2.2 Message Failure Display.

All eight subjects agreed that replacing the equipage/ eligibility symbol in the first line of the FDB with an up-arrow symbol was a desirable method to indicate that a TOC message had been sent. However, six controllers felt that the symbology used to indicate failure of the TOC process was inadequate.

In the candidate design, the receipt of an unable response from the pilot, or the expiration of the transaction timer (time out), caused the up-arrow to revert to a filled diamond in the sending controller's FDB indicating that the position had retained eligibility. The diamond was color coded in yellow to alert the controller. Some controllers expressed dissatisfaction with this design and suggested that the alert be more salient to insure prompt action. Suggested solutions included increasing the size of the diamond as a redundant signal correlated with the color change, and the use of yellow alert coded UNA and TIM abbreviations in the FDB similar to those used in the candidate AA service. Subsequent discussion favored the use of the FDB display of TIM and UNA. The group strongly recommended that these be adopted for all services. In addition, while reversion of the up-arrow to the yellow-filled diamond was seen as an appropriate redundant code for TOC, the group recommended that it be used only with an unable response since a time out event does not close the transaction. In this case, the FDB TIM display, along with a change in the up-arrow color code to yellow, was suggested as a possible solution.

<u>3.2.2.3 Methods for Sending Held Messages in Manual Mode</u>.

As described in section 3.2.2.1 above, the candidate design required a slew entry to the status list item to send a held TOC message when operating in the manual mode. Individual evaluations derived from the design review booklets revealed several suggestions for enhancing the flexibility and ease of sending these held messages. In subsequent discussions, the group agreed that several options should be provided as alternatives to the status list slew entry. These included a slew entry to the FDB preceded by a Data Link key entry, or a keyboard entry of the Aircraft Identification (AID) or Computer Identification (CID).

As a potential aid to selecting and sending TOC messages, the subjects also recommended that future studies test the option of displaying all held message items in the status list as a single group separate from other ongoing transactions.

<u>3.2.2.4 Force and Steal Eligibility Inputs</u>.

Based on the results of earlier studies of the Host/PVD en route Data Link requirements, the candidate ISSS design for TOC provided command options which permitted controllers to force Data Link eligibility to another sector. It also provided an ability to acquire eligibility (steal) without a hand off. To aceommodate procedures used in some ARTCC's, both of these commands provided for an optional suffix (S) to send the appropriate TOC message to the affected aircraft.

Although the operational requirements for these features were recognized by the subjects, concerns expressed the need for strict adherence to procedures to ensure they were used safely. In particular, it was noted that the design could permit inadvertent separation of voice radio and Data Link communications at two different sectors.

Since the frequency change message and eligibility will be correlated in the vast majority of situations, the group recommended that the possibility of error could be minimized through design by modifying the force and steal commands. Under this recommendation, sending the TOC message would occur by default when forcing or stealing eligibility. An optional suffix (I) would be required to inhibit the uplink normally associated with the eligibility change.

3.2.2.5 Additional Command Requirements.

Two new command inputs were recommended by the subjects during group discussion to enhance the usability of the TOC service. In order to simplify the inputs needed to acquire track control from another sector without an offered hand off and to subsequently acquire Data Link eligibility, the controllers suggested that a single command be developed to accomplish both operations simultaneously. Additionally, the group agreed to extensions to the existing command suffix (S) which permits the controller to automatically send the TOC message to a designated aircraft while operating in the manual mode. These enhancements would include a suffix (I) to inhibit an automatic uplink to a designated aircraft while operating in the manual mode. Another enhancement would be the capability to inhibit the uplink to all aircraft being transferred to a selected sector while operating in the automatic mode.

3.2.3 AA.

The individual evaluations and group discussion of the AA service indicated that the candidate design was among the most mature of those tested in this study. All eight subjects agreed that the inputs to manually enter and uplink assigned and interim altitudes were appropriate, and that the FDB display of the content and status of the message provided useful and adequate feedback. The subjects also agreed that the FDB alerting displays for unable and standby responses and expiration of the response timer (time out) were adequate.

Asked if they foresaw any significant possibility that controllers would make undetected errors when uplinking altitudes using this service, none of the subjects indicated that errors would be any more common with Data Link than voice. During discussion, the controllers suggested that the potential for error might be reduced even further by adding reasonableness checks to the software. These could include tests for cardinal altitude values and restrictions for the altitude boundaries of the sector.

3.2.3.1 Deletion of Message "Failure" Displays.

The single major change recommended for this candidate design concerned the procedures used to delete the displays of these failure events and close the transaction. As dictated by the Minimal Operating Performance Standards (MOPS) for Data Link, an unable response from the aircraft automatically closes a transaction, while a standby response is an interim state which keeps the transaction open and which may be followed by a wilco or unable. Likewise, the time out is an alert that a greater than normal period of time has passed since uplinking a message without receiving a pilot response. The time out alert display is based on the expiration of a ground-based timer which does not close the transaction.

The controllers indicated that, to prevent inadvertent errors, different inputs should be used to delete closed transactions (e.g., unable responses), and those which remain in an open state (sent, standby, time out). The unanimously recommended solution was to retain the candidate design's delete command for unable displays, but to require a logic override prefix to the delete command (e.g., /OK) to permit closure of open transactions and removal of the associated alert or status displays.

3.2.3.2 Recommendations for ISSS Changes.

Along with this modification to the delete procedure, the subjects also considered the technical feasibility of a special feature of the ISSS candidate services which permitted the controller to designate more than one aircraft as the receiver of a single altitude, TOC, or MT message. This feature was favorably reviewed by the subjects. However, subjects from the ERST noted that, while current ISSS procedures allow specification of multiple flight identifications (FLID)'s on system hand off inputs, they are not permitted on other system updates, such as AAs. The subjects recommended that this issue, along with the automatic error message delete requirement discussed in section 3.2.1.3, be further investigated. If warranted by these investigations, appropriate recommendations to ISSS developers should be formulated to accommodate both changes.

3.2.4 IC.

As tested in this study, the candidate IC service was accomplished by the pilot appending the aircraft's currently assigned altitude to the wilco downlink response to a TOC message. This value was automatically compared to the assigned altitude in the NAS data base or the interim altitude in the FDB. If no discrepancy was detected, the service was essentially transparent to the receiving controller. However, if the downlinked altitude differed from the altitude held by ATC, the downlinked value was timeshared in the FDB in the altitude field, and a yellow alert coded "E" appeared in the conformance indicator field. If the aircraft failed to downlink the altitude with the TOC wilco, "NALT" was displayed in yellow in the altitude field.

3.2.4.1 False Alarms.

The basic IC design was judged to be acceptable by the controllers. All subjects indicated that the error alerts were adequate, and that the procedures used to clear the error displays were appropriate. However, because of operational procedures that are widely used in sectors handling departures out of approach control facilities, the group unanimously rejected the testing logic of the automated altitude comparison feature.

Specifically, as aircraft transition through en route departure sectors, low altitude sectors, and into high altitude sectors, controllers are not typically required to update the FDB on temporary altitudes sent to the aircraft. In the candidate design logic, this situation would produce mismatch error displays for nearly all aircraft. Such a high false alarm rate would at best cause distraction and an increase in controller workload associated with clearing the alert, and at worst could lead to complacence and a resulting failure to detect legitimate errors.

Because automating the IC procedure was viewed by the test controllers as a valuable Data Link benefit, they proposed an alternative approach to designing the test logic that would reduce false alerts. In this proposal, the automation would first test the downlinked value against any interim altitude displayed in the FDB. If no interim altitude was displayed, the system would compare the assigned altitude in the NAS database with the appropriate value contained in a table of normal departure altitudes. It would make the final error test by comparing the downlinked value with the value in the normal table, if the normal table value was lower than the assigned altitude in the database. The final error test would be made against the assigned altitude if that value were lower.

The table of normal departure altitudes would be created by defining areas in adaptation based on altitude strata. For each stratum, typical altitude clearances for departures would be entered based on aircraft type (jet, turboprop, etc.).

3.2.5 MT.

The candidate MT function permitted the controller to select predefined messages for uplink from a menu designed as an ISSS view. Messages were displayed in list format. Each line contained an alphabetic item identifier, a two-letter indicator of message type, and an abbreviated presentation of the message. Message types included AAs, interim altitudes, and text messages. Messages could be selected for uplink by typing the message identifier or by trackball slew entry.

Evaluations of the menu format were favorable. All subjects agreed that the two-letter message type identifier was useful, but concurred that AAs and interim altitudes should use the identifiers "AA" and "IA" rather than the "QQ" and "QZ" abbreviations associated with the PVD keyboard.

3.2.5.1 FDB Displays for All Control Clearances.

All of the primary objections to the candidate MT design focused on the message status and content displays. While AAs and interim altitudes in the menu used FDB displays that were identical to those used for the AA service, no FDB content or status display was provided for text items.

The decision to limit the text message status/content display to the status list in the candidate ISSS design was based on earlier Host/PVD Data Link research in which this message type was developed for informational and non-control messages. In the present study, the text message type also was used as a means to provide controllers with an ability to uplink speed and heading clearances.

The subject controllers unanimously agreed that FDB status and content displays would be mandatory for all critical and control-related messages. They specifically noted that speed and heading messages should have FDB displays comparable to those provided by the candidate design for altitude clearances, and that these should be consistent across service types. Recommended elements of the displays included direct numeric indication of message content, status abbreviations, and alert codes.

The argument for self-sufficient FDB content and status displays for all control clearances was supported by specific input from subjects drawn from the ERST. These individuals noted that the large number of important views that controllers will need in the ISSS ATC environment will make display "real estate" scarce. Thus, every effort should be taken to make critical Data Link functions operable without reliance on the status list view.

In a discussion of approaches for developing FDB status and content displays for speed and heading clearances, group suggestions included possible use of fields in the fourth line of the ISSS FDB, and timesharing or temporarily overriding correlated data fields in lines two and three of the FDB.

3.2.5.2 Manual Speed and Heading Entries.

The controllers also recommended that, in addition to the menu method for uplinking predefined clearances, manual keyboard entry methods for sending speeds and headings be developed using the candidate AA service as a model. Finally, a majority of the subjects did not predict that the use of the menu to uplink clearances would result in a significant potential for undetected entry error. However, they reiterated the recommendation that the use of reasonableness checks be explored.

3.2.6 CB (Free Text).

The CB service design permitted controllers to enter an unconstrained string of text for uplink to one or all aircraft in the airspace sector. No FDB displays were provided. A status list display provided message status and a truncated content display consisting of the first six characters of the typed message.

Opinions regarding the adequacy of the displays differed widely among the subjects in the individual design review booklets. While some found that the status list display was adequate, others felt that an FDB display of any alert status would be needed. Likewise, the preferred completeness of content information in the status list varied from the minimal characters used in the candidate design to an ability to access the complete message by command entry.

Analysis of the subjects' written comments and group discussion indicated that these widely differing views were based on the applications of the service that had been made by different controllers during practice exercises. The service title of "CB" had been adopted during prior research which had demonstrated that free text entry of messages tended to be inefficient and error prone. Because of these findings, it was recommended that the function be used only in a backup mode to deal with situations in which radio communication was impossible and none of the Data Link control services provided the needed message.

Some subjects in the present study used the CB service to create speed and heading clearances not contained in the menu. In their individual reviews, these controllers were most critical of the absence of the FDB status display, and the truncated content display in the status list. Group evaluation which followed an explanation reemphasizing the intended backup use for the service led to two recommendations.

The group agreed that the truncated content display in the status list should be retained, but that an ability to display the full message in the response area (RS) view by a command input should be added. The controllers also recommended that an ability to select multiple specific aircraft as message addressees be added to the existing ability to select one or all aircraft.

3.2.7 Data Link History Display.

A final controller concern was controller short term memory for messages sent using Data Link. When reviewing Data Link displays of message content and status, some subjects noted that they had experienced instances where they were unsure that a clearance that they intended to issue had, in fact, been sent. In other cases, they could not remember the content of a message that they confidently recalled having sent. Suggested solutions included increasing the persistence of the status list display of a message after the aircraft's wilco response had been received.

It was noted that similar lapses in short term memory had been reported by terminal controllers during ARTS IIIA Data Link service development. Although the phenomena also occurs with voice radio communications, it should be possible to remedy the problem with Data Link by providing a display of an aircraft's message history. The solution used for terminal development was a history list of the last five transactions that could be retrieved for any aircraft by a command input.

As a result of this discussion, the group recommended the development and testing of a history display for the ISSS Data Link services. Suggested methods included a history list similar to the terminal system, or annotation of the ISSS electronic flight strip fields to show updates that had been accomplished via Data Link.

3.3 FULL SCALE SIMULATION TESTING.

The full scale simulation phase of this study was conducted primarily to provide a realistic set of ATC experiences for making a number of comparative and predictive judgments about the impact of the initial ISSS Data Link services. The test runs also were used to elicit final summary evaluations of the candidate ISSS Data Link service designs, and as an opportunity to collect quantitative data on controller use of the Data Link and voice communication channels.

3.3.1 ISSS Communications Performance.

Many of the benefits predicted for implementing Data Link ATC services in domestic airspace have been associated with the increased communications capacity that they will offer to controllers and aircrew. As previously noted, the simplex voice radio system has been cited as a major limitation to effective ATC operations, and the provision of Data Link services is expected to alleviate this communication bottleneck.

In order to generate a preliminary estimate of the extent to which the availability of ISSS Data Link ATC services would reduce congestion on the radio channel, data were collected on controller use of the voice frequency. Measures were obtained during voice test trials and during those in which the controllers were able to freely choose between voice and Data Link communications. For each of the four airspace sectors, simulation computers recorded the number of PTT microphone activations that occurred during a 50-minute run as a measure of the number of messages sent by a controller. In addition, the computers accumulated the total time during which the radio channel was occupied by a controller during a test run by summing the PTT-to-release intervals.

As shown in figure 3, the subjects' use of Data Link for ATC communications dramatically reduced their reliance on the voice channel. The mean number of voice messages per sector dropped from 167 to 56, while total channel occupation time by the controller was reduced from 610 to 189 seconds. Statistical tests indicated that these reductions were highly significant (PTT $t = 6.624$, $df = 7$, $p = 0$, time $t = 8.429$, $df = 7$, $p = 0$).

Generalized as percentages, with 80 percent of the aircraft in the scenarios equipped with Data Link, and without including frequency usage by the simulation pilots, the results translate to a 66 percent reduction in the number of messages and a 69 percent reduction in channel occupation time. It is interesting to note that these findings closely corroborate those obtained in earlier Host/PVD en route Data Link testing (Talotta, et al., 1990). In that study where different test scenarios and airspace were used, and with a more limited set of Data Link services, channel occupation time was reduced by 28 percent with 20 percent of the aircraft Data Link equipped, and by 45 percent with 70 percent of the aircraft Data Link equipped.

3.3.2 Controller Workload During Test Runs.

Each of the subjects completed the SWAT scale development task prior to participating in the full scale simulation test runs. The ordered card sorts generated by the individual subjects were used as input to the SWAT scaling algorithms. The algorithms produced the unidimensional, interval level workload scale values that would be used to interpret the ordinal ratings of 1 to 3 on the time, effort and stress scales.

The overall level of agreement among subject orderings of the 27 possible combinations of time, effort, and stress was assessed by computing Kendall's Coefficient of Concordance. The W statistic attained a value of 0.81. The guidelines developed for SWAT analysis state that values of 0.75 and above are indicative of a relatively homogeneous group. Thus, a single scaling solution was used to capture the subjects' composite view of the way in which the time, effort, and stress factors combined to produce various levels of workload.

Axiom tests performed on the average rankings for the eight controllers produced a minimum number of violations under the additive model. The final scale values for transforming the ratings reflected approximate levels of importance of 27 percent for time, 28 percent for effort, and 45 percent for stress.

Instructions to the subjects emphasized that after completing each test run they were to rate the overall workload that they had actually experienced. The raw workload ratings collected were transformed to SWAT scores by referring to the 0 to 100 group scale described above. All statistical analyses were performed on these scores.

A multivariate analysis of variance performed on the SWAT scores for each test condition revealed no statistically significant difference in perceived workload between voice and voice plus Data Link simulation runs ($F_{1,7} = 2.92$, $p = .13$). However, as illustrated in figure 4, regardless of the communication system, the controllers rated their workload as significantly lower when using the ISSS

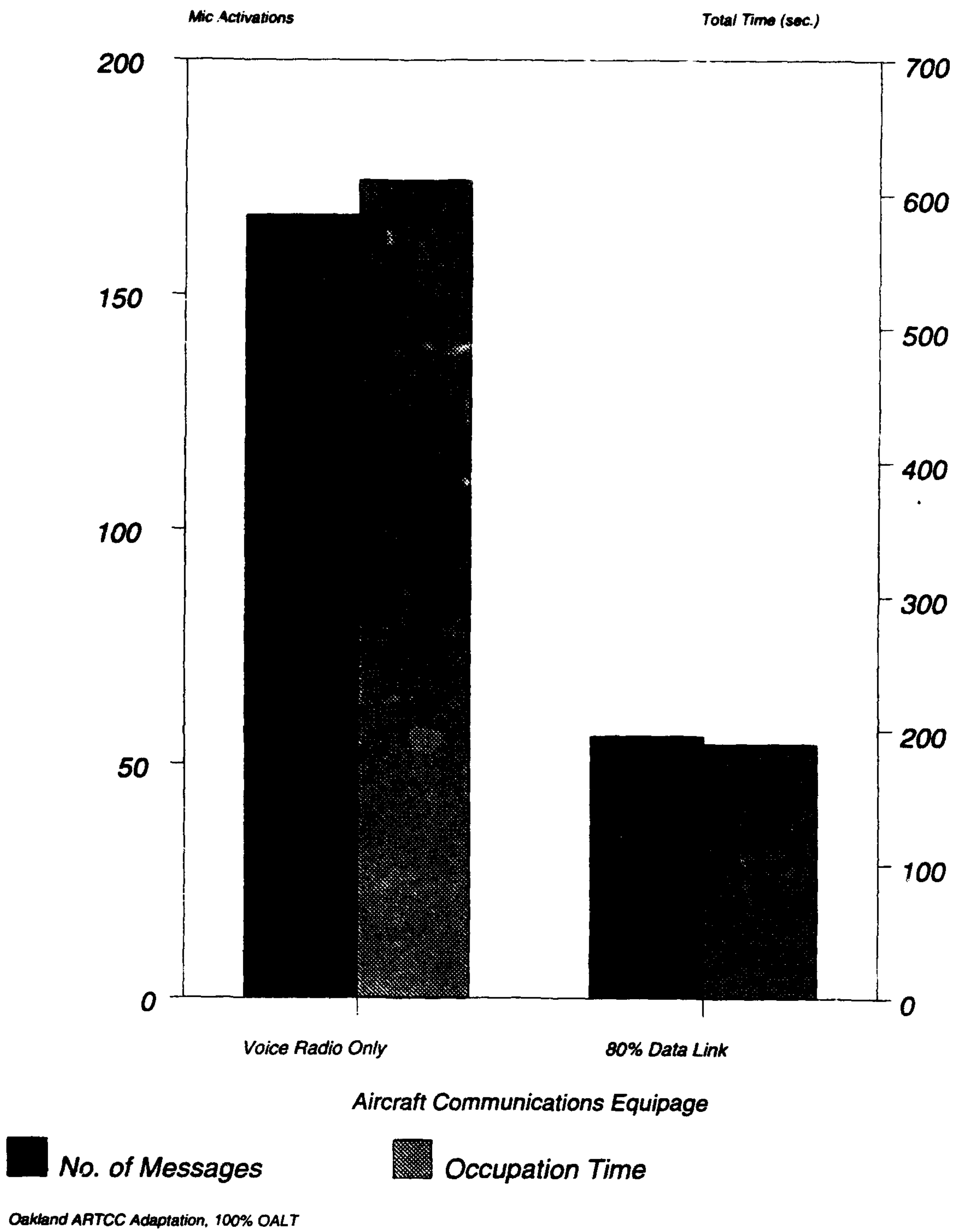

FIGURE 3. EFFECTS OF DATA LINK ON VOICE RADIO USAGE

common console than when working on the PVD workstation ($F_{1,7} = 12.4$, $p=.009$). The interaction between ATC system type and communication system was not significant ($F_{1,7} = .009$, $p = .93$).

Written controller comments suggested that a number of factors affected perceived workload during the 100 percent of OALT test runs. Of 18 comments, 9 cited controller or simulation pilot errors as contributors to increased workload. Four noted problems with the candidate Data Link designs, which included the lack of FDB displays for speed and heading clearances identified during the design review. Comments directly related to communications noted Data Link improved time management, especially with the ISSS designs. One subject also indicated that workload was higher under voice conditions because of pilot requests for message repeats.

With respect to the impact of Data Link on workload, the SWAT findings agree with prior controller assessments obtained following test runs comparing voice radio communications to voice plus Data Link. Results of earlier simulation studies examining both en route and terminal systems indicate that controllers' perceive their workload to be no greater than that experienced with voice radio alone, or moderately higher. Variations appear to depend on subject training and familiarity with the communications system and the test airspace. The substantially identical result obtained in the present study indicates that, even when using the unrefined candidate service designs, controllers find that providing Data Link ATC services with the ISSS produces no different workload effect on the user than that experienced on the PVD system.

Caution should be exercised when interpreting the reduction in workload reported by the controllers when operating ISSS., It cannot be concluded from these data that the operational ISSS will result in reduced controller workload because the prototype workstation simulated only partial ISSS functionality for the radar controller position. It did not include the electronic flight strip implementation or associate controller positions. Nevertheless, the finding is of some interest since it suggests that if some controllers experience an increase in workload with Data Link usage, it may be ameliorated by some of the enhancements associated with the new human-computer interface.

3.3.3 Projected Impact of Data Link and ISSS.

Following all four full scale test runs, the subjects were asked to make a number of final ratings aimed at summarizing and quantifying their overall perceptions of Data Link. The first was designed to permit the controllers to make projective evaluations of the impact of Data Link on controller and system performance. Unlike the ratings made after each test run, these scales asked the subjects to use their operational expertise and the simulation experiences as a basis for predicting the impact of Data Link in an operational implementation. They were instructed to assume a fully designed and tested system. AHP techniques were used to obtain comparative ratings of the relative effects of the PVD and ISSS implementations under voice only and voice plus Data Link communication conditions for four variables: system capacity, system safety, controller workload, and controller efficiency/ productivity. For each variable, the AHP analysis was used to produce relative values ranging between 0 and 1.0 based on all possible comparisons of the combination of communication condition and controller interface type. Thus, the differences between values on the scale are meaningful in examining these results rather than the absolute values.

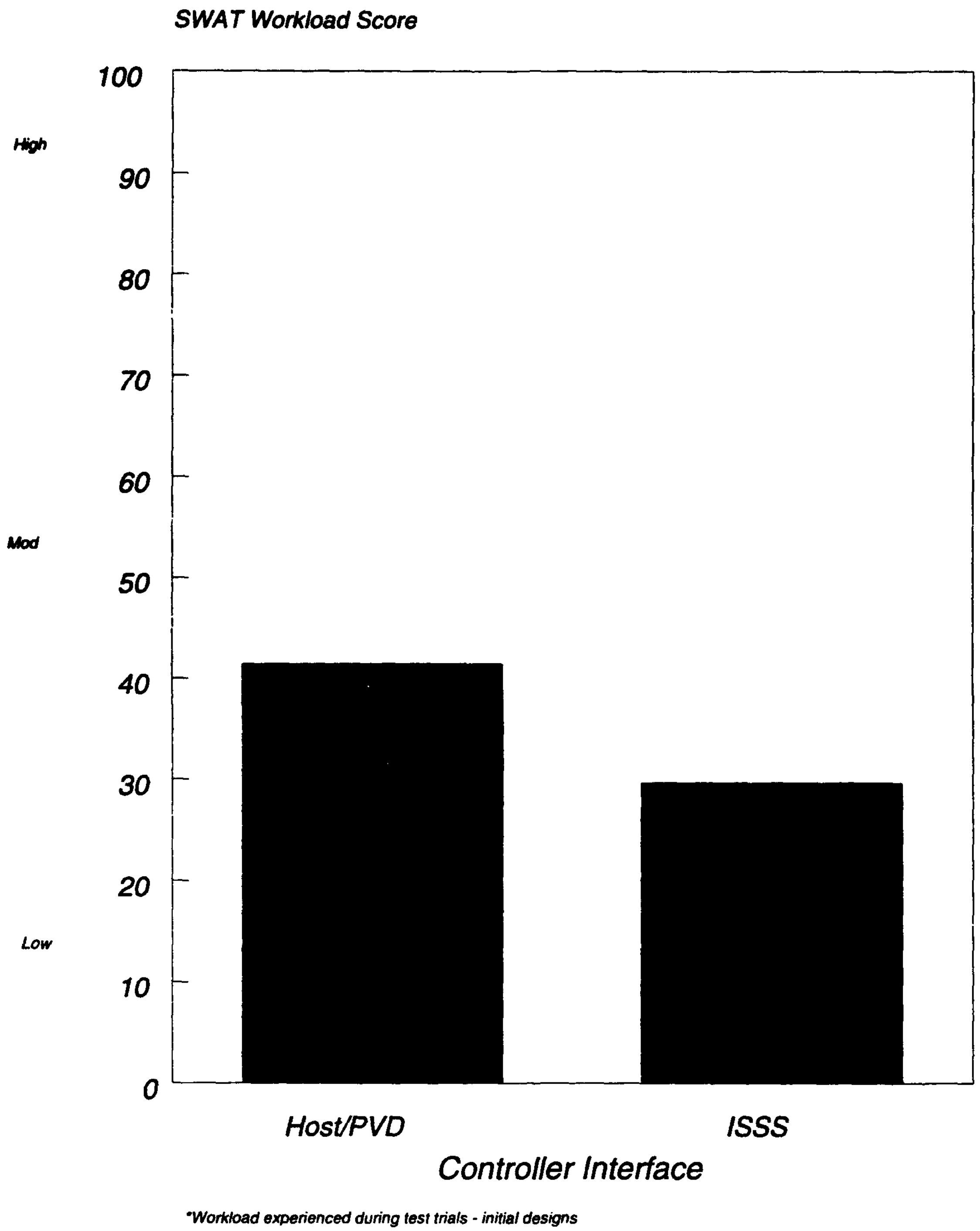

FIGURE 4. PERCEIVED CONTROLLER WORKLOAD DURING ISSS AND HOST PVD TEST RUNS

Multivariate analyses of variance were performed on each of the projected variables. Neither projected controller workload nor system capacity were found to differ significantly as a function of controller interface type or the availability of Data Link ($p>.05$).

Significant differences among the four system combinations were detected for the safety ($F_{1,7} = 7.16$, $p< .05$) and controller efficiency/productivity ($F_{1,7} = 87$, $p< .001$) variables. Figure 5 presents these results as AHP mean difference scores computed by subtracting each subject's AHP value for the PVD Data Link, ISSS voice, and ISSS Data Link conditions from that obtained for the existing PVD voice baseline.

As shown in the figure, the controllers predicted relatively higher safety and controller efficiency for all three future system possibilities relative to the current PVD/voice system. Newman Keuls post hoc tests on the means indicated that both Data Link implementations would produce greater system safety than the existing voice system. They also showed that the ISSS Data Link combination would yield greater safety than the PVD Data Link system ($p<.01$). This suggests that the positive impacts of Data Link and of the new ISSS on safety would be additive in their effects.

As illustrated in the figure, the largest predicted impact of the ISSS Data Link combination was its effect on the ability of the controller to efficiently use these resources to expedite the flow of air traffic. Statistical testing showed that while both the addition of Data Link and the implementation of the ISSS system would affect controller productivity, the combination of the two would have a positive, interactive effect greater than the sum of the two alone ($F_{1,7} = 14.1$, $p<.008$).

3.3.4 *Summary Evaluations of ISSS Candidate Data Link Service Designs*.

A second group of ratings completed by the controllers after the full scale simulation runs was aimed at providing an overall summary evaluation of the candidate ISSS service designs as implemented for this study. For each of the services the controllers were asked to make two ratings. The first of these was an evaluation of the operational effectiveness and suitability of the service. For this rating, controllers were instructed to focus on the extent to which the service included all of the functions and capabilities needed to support operational requirements in a field en route ATC setting.

The second rating was an evaluation of the acceptability of the design to controllers and their preference for its features. In this case, the subjects were asked to focus on usability and compatibility with normal controller practice, regardless of the design's effectiveness. Subjects were explicitly instructed that, while the two dimensions of effectiveness and acceptability could be correlated, it is possible for a design to contain all required operational features and be difficult to use, or for it to be highly usable but fail to provide all features needed to support ATC operations.

Ratings in each case were accomplished by first indicating whether the service was "not operationally suitable" or "completely unacceptable". Alternatively, if the service met at least some operational

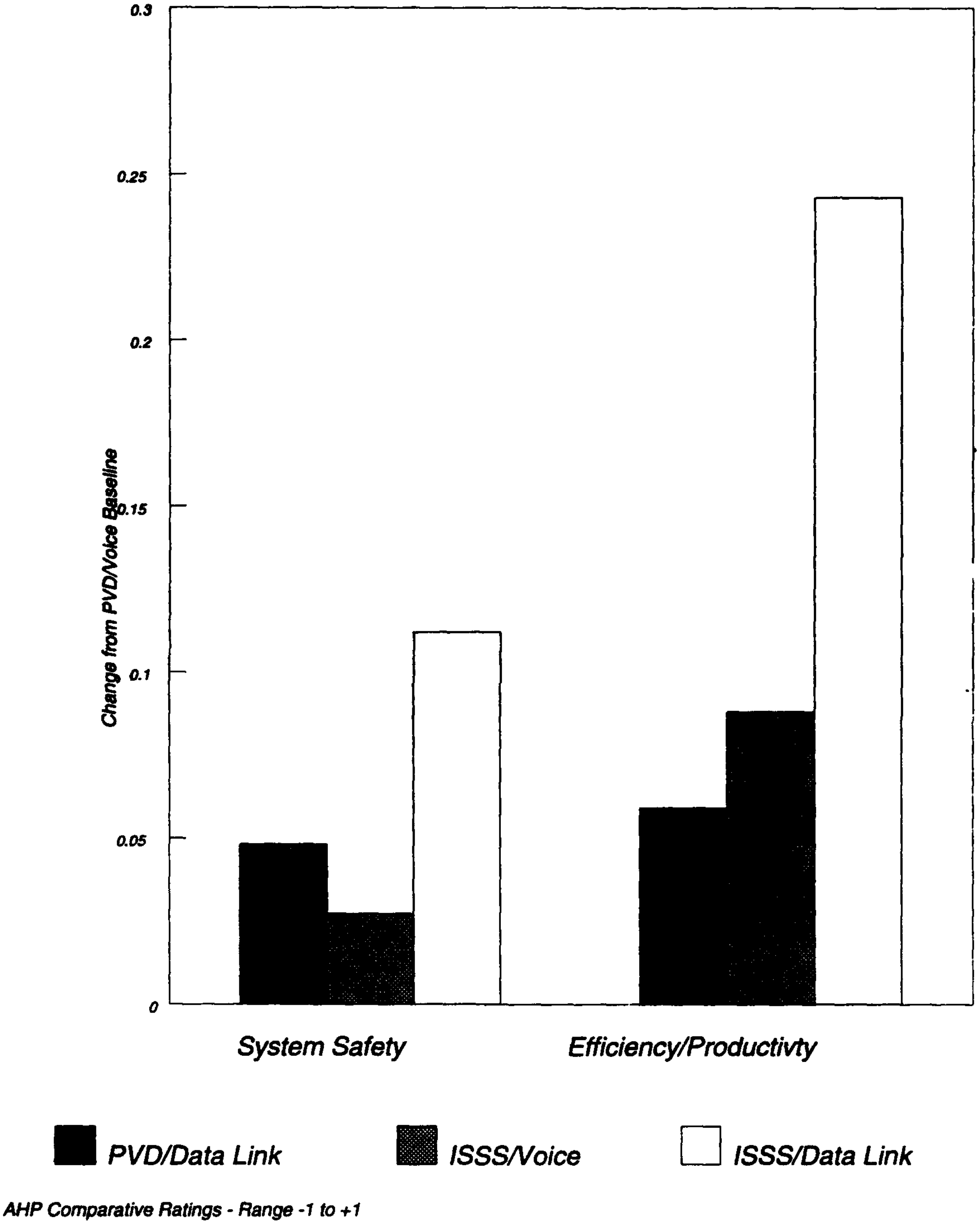

FIGURE 5. COMPARATIVE PROJECTIONS OF EFFECTS ON SYSTEM SAFETY AND CONTROLLER EFFICIENCY/PRODUCTIVITY

requirements, or was at least minimally acceptable, they rated the service on ordinal 7-point scales ranging from "minimally effective" (7), to "highly effective" (1), and "acceptable but not preferred"(7) to "highly preferred" (1).

For quantitative analysis purposes, the data were transformed such that "not operationally suitable" or "completely unacceptable" ratings were scored as 1, and ratings of 1 to 7 were scored as 8 through 2, respectively. These transformed scores for each variable were subjected to Friedman Two-Way nonparametric analyses of variance to assess the significance of differences in ratings among the services.

Statistically significant differences among the services were detected for both operational effectiveness/suitability ($Chi^2 = 13.5$, $p<.009$) and for controller acceptance/preference ($Chi^2 = 13.62$, $p<.008$). The source of these effects can be identified by examining table 2. which presents the median ratings for the transformed data (range 1 (lowest) to 8 (highest)), and by inspecting figures 6 through 10 which present the raw ratings in terms of frequency distributions.

TABLE 2. MEDIAN SUMMARY RATINGS OF THE CANDIDATE ISSS DATA LINK SERVICE DESIGNS

TRANSFORMED RATING MEDIANS

Range: 0 (not effective/acceptable) to 8 (highly effective/preferred)

Service*	Operational Effectiveness /Suitability	Controller Acceptance /Preference
TOC	7.5	6.5
AA	7.0	7.0
MT	6.5	6.0
CB	5.5	5.0
IC	3.5	2.0

* TOC -- Transfer of Communication
AA -- Altitude Assignment
MT -- Menu Text
CB -- Communications Backup
IC -- Initial Contact

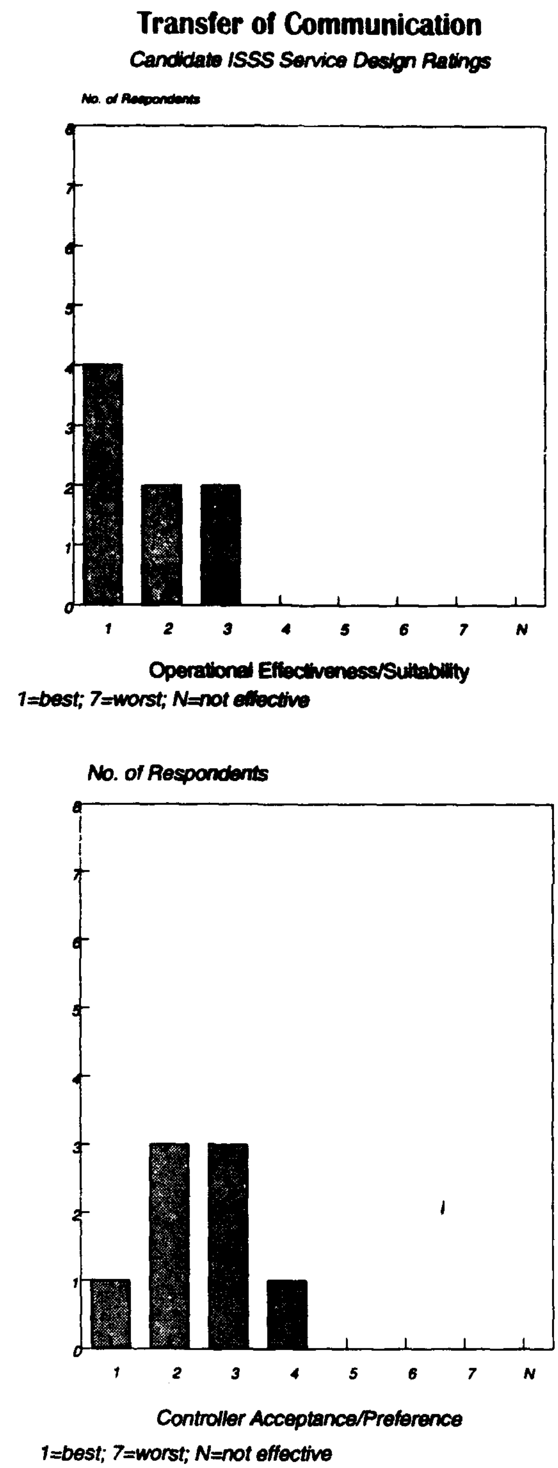

FIGURE 6. SUMMARY EVALUATIONS OF THE CANDIDATE TOC DESIGN

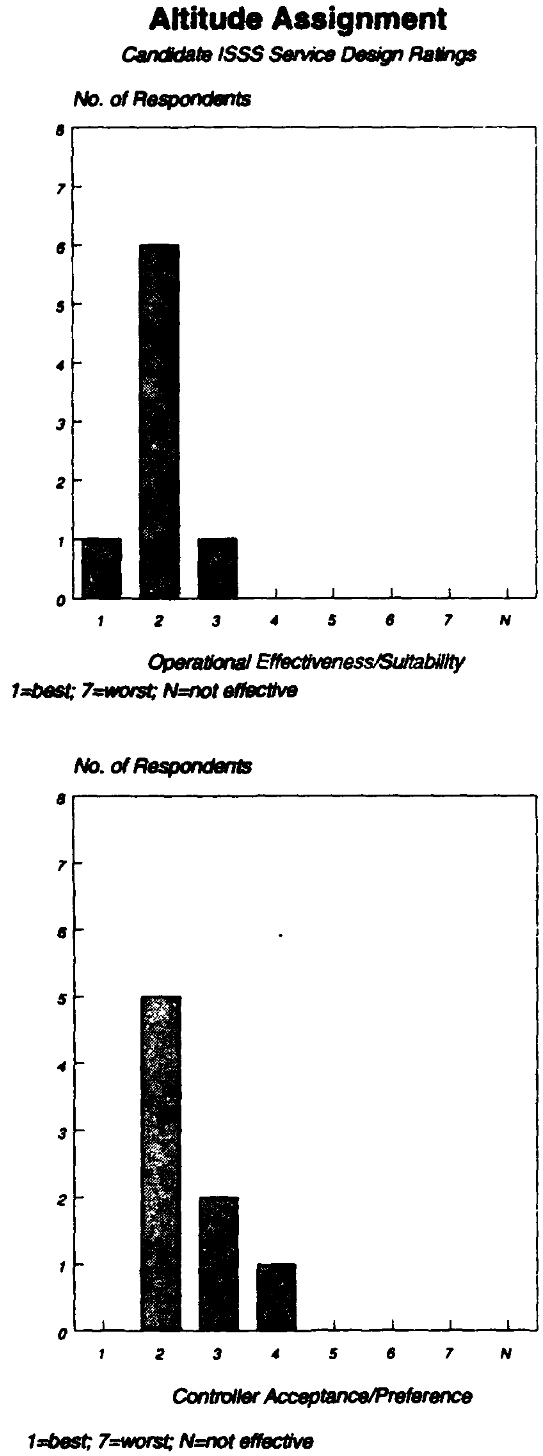

FIGURE 7. SUMMARY EVALUATIONS OF THE CANDIDATE AA DESIGN

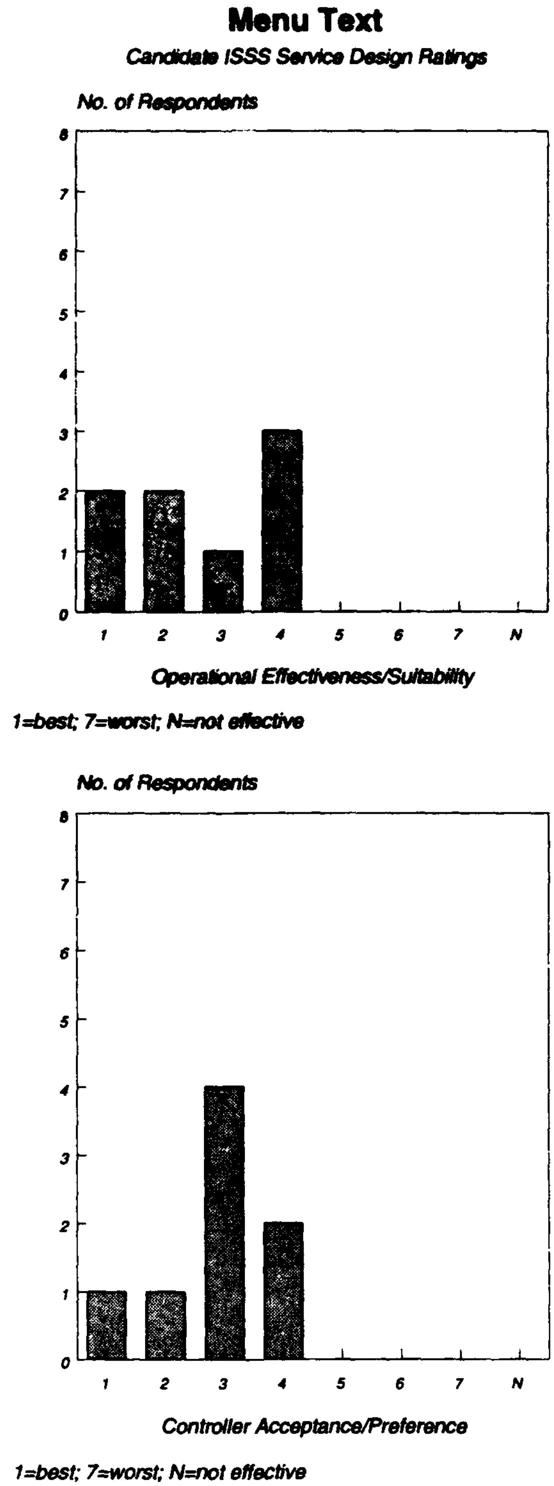

FIGURE 8. SUMMARY EVALUATIONS OF THE CANDIDATE MT DESIGN

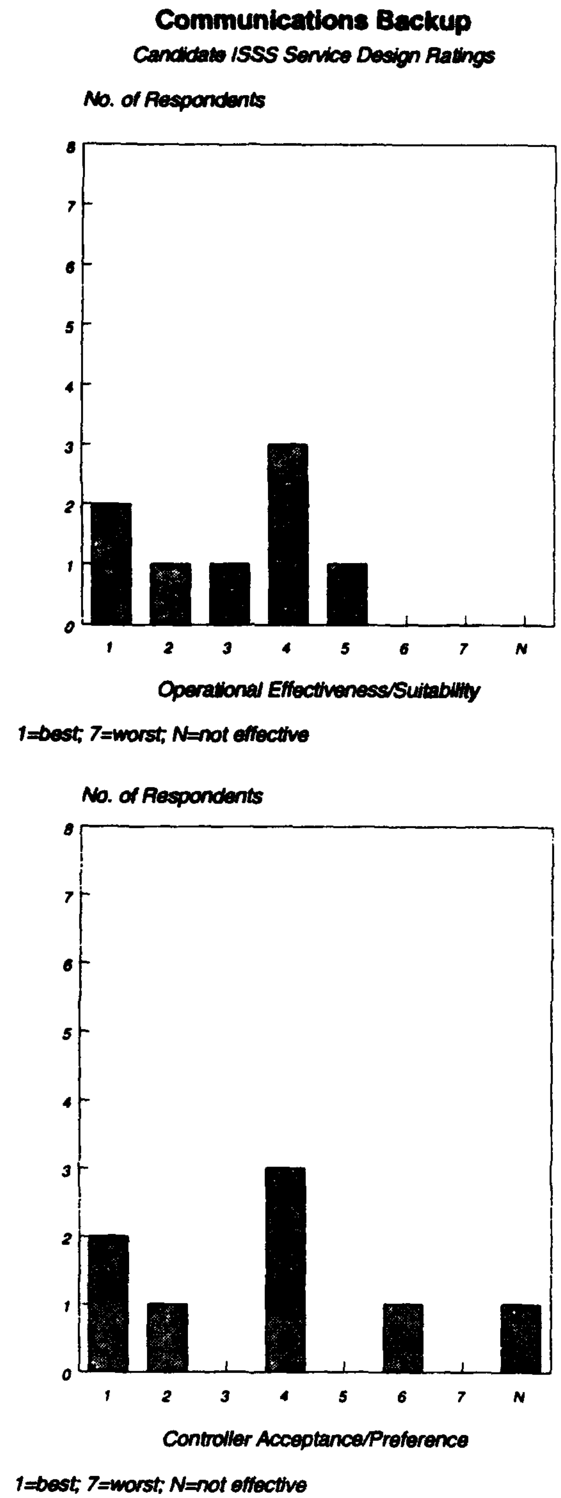

FIGURE 9. SUMMARY EVALUATIONS OF THE CANDIDATE CB DESIGN

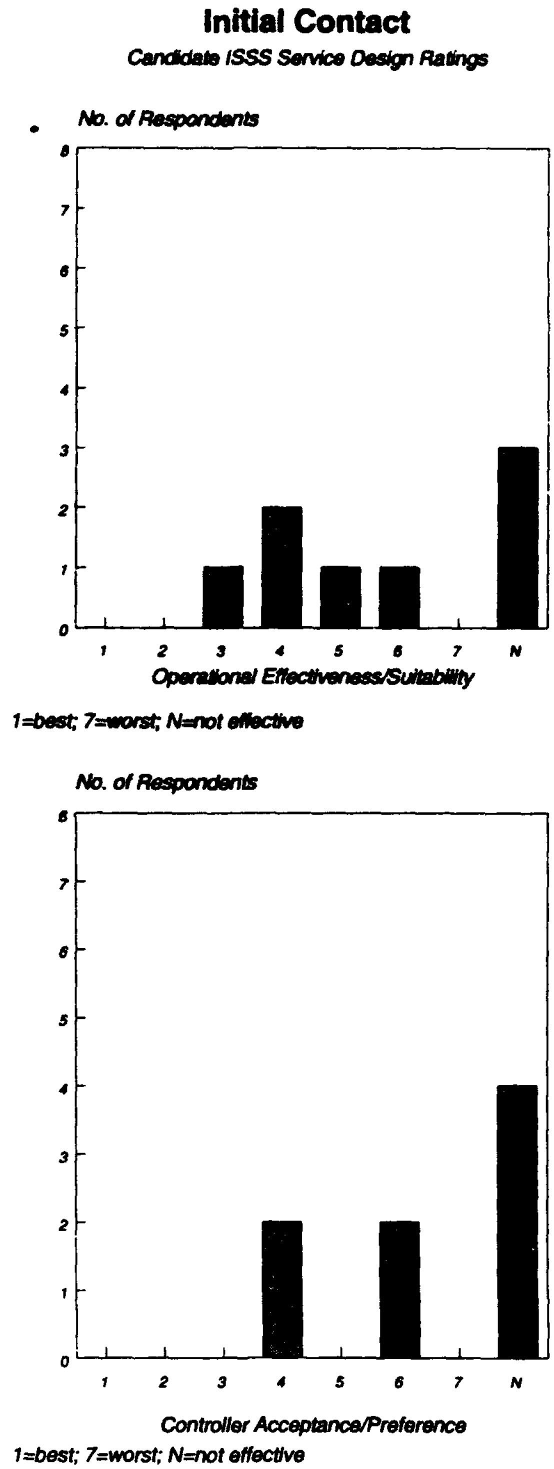

FIGURE 10. SUMMARY EVALUATIONS OF THE CANDIDATE IC DESIGN

As shown in the table, TOC and AA were highly rated on both evaluation dimensions. Neither service design received a "completely unacceptable" nor "not operationally suitable" rating. Furthermore, all of the controllers rated these two services at or above the scale midpoints in effectiveness and acceptability.

The MT function received the next highest ratings on both dimensions, with all ratings at or above the midpoint of the scales. As indicated by subject comments on the ratings, the somewhat lower scores than those obtained for TOC and AA are attributable to an issue in the application of MT that arose during the design review. For the present study, clearances were included in the menu to permit subjects to control headings and speeds during test runs. This was accomplished by using text items in the menu. While altitude items in the menu were originally designed to provide FDB status and content information, text items had been designed for sending non-critical, non-control messages. Consequently, no explicit FDB content and status indication or status list content indication was designed for these items. When using the text items in the menu for sending clearances, subjects found the lack of FDB content and status information to be unacceptable, and recommended that any control clearance sent by MT be provided with this feedback data.

The CB service received only one rating below the scale midpoint for operational effectiveness, but received mixed ratings for controller acceptance, with raw ratings ranging from highly preferred (2) to completely unacceptable. This diversity of ratings appears to reflect differential opinions regarding the way in which the service will be used in an operational implementation. During the testing many subjects used the function to send clearances that were unavailable on the menu. This practice concerned some subjects because of the potential for high error rates when using free text entry. The concerns were exacerbated by the lack of FDB displays and abbreviated status list content information in the CB design.

It should be noted, however, that the design of the candidate service was based on an assumed set of operational procedures which would limit its application. CB was developed for non-critical, non-control messages, except in the case of lost radio communications. Thus, it is likely that the reasonably high operational effectiveness ratings accompanied by mixed acceptability ratings reflect this concern over how the CB function will be used rather than any flaw in its usability or operational suitability.

The lowest overall ratings on both dimensions were received by the candidate IC service design. Three of the eight subject controllers indicated that the design was "not operationally suitable," and only one rated it above the midpoint on the operational effectiveness/suitability scale. Four of the subjects rated IC as "completely unacceptable" to controllers, and none rated it above the midpoint on the acceptance/preference scale.

These low ratings can be directly attributed to a flaw in this service that was identified by the controllers during the design review phase of the study. As described in section 3.2.4.1, the IC service used an automatic check of the downlinked altitude against the assigned altitude to verify concurrence. The subjects noted that there are several conditions in operational environments where the data base and data block assigned altitude indication do not correlate with the legitimate AA of the aircraft.

Because of these situations, the candidate service design would display an unacceptably large number of error messages to the controller.

3.4 FINAL DEBRIEFING.

The full scale simulation phase of this study was followed by a final debriefing session. This debriefing revisited the designs of the candidate Data Link services and addressed a number of general topics regarding the development of Data Link ATC services and the impact of implementing these services in the NAS. Results directly concerned with design changes to the candidate services were combined with those from the design review phase of the study, and are included under section 3.2 of this document. Additional findings from the debriefing follow.

3.4.1 Comparison of Data Link in the Host/PVD and ISSS.

Discussion of the relative advantages and disadvantages of implementing Data Link ATC services in the ISSS and Host/PVD systems confirmed the individual projective rating results. Despite the detailed design changes recommended during the study, as a group, the controllers preferred Data Link implemented in ISSS over the PVD. Factors influencing this preference included a greater ability to use implied commands in the ISSS designs, the availability of color coding for alerts, the improved Data Link equipage/eligibility symbology in the FDB, and the ability to use a single command to uplink a message to multiple aircraft.

The controllers also noted several issues that must be resolved to insure that the ISSS Data Link interface will be operationally suitable. They reiterated that the current ISSS specification does not provide for some of the command input requirements that enhance the efficiency of Data Link keyboard entry tasks. These limitations include the inability to automatically delete an input error message by retyping, and that designation of multiple aircraft is permitted only in hand off messages.

In addition, the subjects emphasized the importance of insuring that the final versions of the keyboard, numeric keypad and trackball device for the ISSS common console be selected to optimize rapid and accurate operation.

3.4.2 Future Data Link Development Requirements.

Asked to recommend high priority issues in future development of ISSS Data Link services, the controllers concurred on three topics. First, they repeated their recommendation that future testing be conducted in a multiple console per sector configuration. Such a configuration is expected to be the norm in ISSS operations, and will provide not only greater realism during testing, but will offer the opportunity to explore Data Link functions that can be performed by associate ("D" and "T") controllers.

Secondly, the group indicated that it will be imperative to design a fully functional capability to efficiently communicate route changes using Data Link. This functionality must include a capability for controllers to generate a new route in real time and send it to an aircraft. It also must have a capability to receive a downlinked route request from the aircraft, edit the request, and uplink the modified version to the aircrew for direct input to the flight management system.

A final recommendation concerned the process by which the results of developmental studies are carried forward to guide implementation and operational testing and evaluation (OT&E). The controllers were aware that, in the current system, human interface requirements derived from developmental research are documented in functional specifications that are used to guide implementation. However, the functional specifications do not contain the rationale upon which the characteristics of particular design feature were based, nor do they document recommended controller procedures for safe and effective use of the design.

It was noted that no official vehicle exists to guarantee that this information is provided to implementers and OT&E personnel as part of a unified package of informational and guidance materials to accompany the functional design specification. The controllers noted that Data Link communications differ from voice radio communications in unique ways, and that they broadly impact strategies for performing ATC tasks. Because of this, they argued that rationales and procedures generated during the development process were necessary components of the service designs. They recommended that approaches be explored to extract this information from study reports and to embody it in an FAA document that will be used to task operational evaluators and implementers.

3.4.3 Effects of Implementing Data Link in En Route ATC.

The subjects also were asked to comment on their projective ratings of the impact of implementing Data Link ATC services. Corroborating the ratings, the group did not see Data Link as a technology that would significantly affect controller workload or system capacity.

The subjects noted that Data Link introduces additional visual monitoring demands to the controller's task. However, they did not feel that workload would increase with an optimized display interface and with the ability to offload some communication tasks to an associate controller. The controllers also emphasized that absolute changes in system capacity could not be achieved by Data Link, since maximum capacity levels are determined by the inherently limited capacity of airports to receive and launch aircraft.

In agreement with their individual projections, a majority of the subjects did foresee significant changes in system safety and controller efficiency and productivity with the introduction of Data Link ATC services. Predicted safety effects were attributed to the reduction in common communications errors associated with the voice radio system discussed earlier.

Discussion of the positive impact on controller efficiency and productivity in en route ATC operations indicated that this effect would be a direct outcome of providing a second communications system operating in parallel with the existing voice channel. As noted above, the subjects did not see this increase in communications capacity as directly affecting absolute system capacity. However, they were confident that it would make controllers significantly more able to efficiently use available capacity.

A specific example of Data Link producing an increase in <u>effective</u> capacity is the situation where an en route airspace sector must enforce miles-in-trail restrictions on airport departures. According to the controllers participating in this study, the resulting aircraft delays are not introduced because of lack of available airspace or runway limitations at destination airports. Instead, they are created by the inability of the controller to communicate effectively with all of the aircraft that would be present in the sector if the restriction were not imposed.

The subjects argued that, in such situations, Data Link will provide the additional communications capacity needed to prevent such costly delays. Hypothetically, a single controller, or a radar controller and an associate would be able to conduct simultaneous communications, maintaining traffic flow levels that would be impossible under the current broadcast voice radio system.

3.4.4 MOPS Compliant IC Procedures.

As an adjunct to the final debriefing, the controllers participated in a structured discussion focused on the effects of altering the IC service to become compliant with the Data Link MOPS. The IC service which was tested during the present study required the pilot to downlink his AA in conjunction with the wilco to a TOC message. As Data Link eligibility changes to the receiving controller with the wilco receipt, this altitude is transferred over ground systems and is automatically checked against the aircraft's flight plan. An error message is presented in the FDB on the receiving controller's radar display if the AA message fails to match the stored flight data.

The recently published Data Link MOPS dictates that, while the aircraft may downlink its AA with the TOC wilco, it also is permitted to send the altitude as a separate message directly to the new controller. Thus, the IC service will require redesign to accommodate this option.

The primary issue that was considered during the discussion was the potential impact of time delays in the modified design. Normally, sending the AA with the TOC wilco will produce a nearly simultaneous transfer of Data Link eligibility and altitude check. However, a separate AA downlink could result in a considerable delay between the receipt of eligibility and the confirmation that the pilot's intended AA conforms with the flight plan. The length of this delay would depend upon a combination of realized system transmission times, the design of the flight deck Data Link interface, and aircrew procedures.

After viewing a simulation of this alternative procedure, the subject group unanimously decided that excessive time delays will be intolerable in the IC process. The stated basis for this opinion was that, before controllers can begin to safely issue clearances to an aircraft entering their sector, they must have reliable knowledge of pilot intent. If the IC message is delayed, an unsafe situation could result where aircraft traverse airspace in which the ATC system cannot effectively communicate control messages.

4. CONCLUSIONS.

The results of this study support the following conclusions regarding: (1) initial en route Data Link air traffic control (ATC) services for the Initial Sector Suite System (ISSS), (2) required changes to the candidate service designs and the prototype simulation system, and (3) the projected impact of Data Link on ATC system performance.

a. The findings derived from the full scale simulation phase of the study indicate that Data Link ATC services are fully compatible with the ISSS. Specifically, the results predict that the availability of ISSS Data Link will significantly expand communications capacity, will not adversely impact controller workload, and will enhance system safety. Furthermore, quantified controller judgments indicated that the combination of ISSS and Data Link will produce a significantly greater positive effect on controller efficiency and productivity than the implementation of either system alone.

b. Results of the design review process revealed a number of deficiencies in the candidate versions of the initial ISSS Data Link ATC service designs, and generated design changes to remediate these deficiencies. Requirements for modifications and enhancements to the candidate service designs are fully described in the results, and key changes are listed in the recommendations section of this report.

c. The participating controllers favorably evaluated the ISSS prototype simulation system as a test bed for continued Data Link service development. Suggested improvements to the system included the addition of a limited number of additional ISSS views and command functions, enhancement of the simulated aircraft models, and the expansion of the system to multiple common console suites.

5. RECOMMENDATIONS.

The following recommendations for future actions toward the development of Data Link air traffic control (ATC) services for implementation on the Initial Sector Suite System (ISSS) are derived from the results and conclusions of the present research.

a. This preliminary design development study produced positive controller assessments of the impact of Data Link in the domestic en route ATC environment, and evidence that these effects will be enhanced by the improved controller interface associated with the ISSS. Therefore, it is recommended that the Federal Aviation Administration (FAA) should pursue continued development of Data Link ATC services for the ISSS, and that it should integrate these services with the ISSS implementation schedule at the earliest feasible opportunity.

b. Each of the modifications and enhancements to the candidate ISSS Data Link ATC service designs recorded in the results section of this report are recommended for implementation and subsequent controller testing in the ISSS prototype simulation system. These recommendations include, but are not limited to, the following:

1. Full data block (FDB) message status and content displays must be developed for all uplink messages involving ATC instructions.

2. Specific speed and heading control services should be developed based upon the model provided by the existing AA services. The features of these services should include FDB status and content displays, manual entry and menu selection methods for message composition and uplink, and consistent alert displays.

3. Logic checks requiring deliberate override command inputs should be added to prevent inadvertent deletion of open Data Link transactions.

4. The initial contact (IC) service must be modified to prevent a high incidence of false alarm alerts in situations where the aircraft's true assigned altitude (AA) is not reflected in the controller's FDB or the National Airspace System (NAS) data base.

5. A capability should be developed and tested to display an historical record of Data Link transactions that have been successfully completed with an aircraft.

c. In order to facilitate Data Link integration, recommendations should be forwarded to the ISSS program to modify existing command input specifications. The specification requiring a keyboard entry to clear entry error messages should be modified to permit automatic deletion of the error message upon retyping. The capability to specify multiple flight identification (FLID) entries with a single hand off entry should be extended to all Data Link messages.

d. In response to the current Data Link Minimal Operating Performance Specification (MOPS) regarding options for downlinking the IC message, the controller participants recommend that the altitude be appended to the TOC response. To maintain system safety, any other option should result in time delays for receipt and evaluation of the altitude which are no greater than those associated with the recommended procedure.

e. Future developments of Data Link ATC services for the ISSS should include testing with multiple console per sector suites. They should also include the evaluation of distributing Data Link communications functions among the radar and associate controllers. Finally, testing should explore methods for utilizing the fourth line of the ISSS FDB and the electronic flight strip displays as Data Link interaction tools.

f. In order to preserve and effectively apply the full range of findings obtained in Data Link design development studies, it is recommended that an official FAA documentation vehicle be created to record design rationale information and procedural recommendations. This publication should accompany the functional design specifications for Data Link ATC services as additional guidance for development of operational software, operational test and evaluation, and implementation.

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APPENDIX A

ISSS DATA LINK CANDIDATE SERVICE DESIGN DESCRIPTIONS

NOTES ON CONVENTIONS USED IN DESCRIPTIONS

In the following ISSS common console service descriptions:

- Two trackball keys are used. Trackball ENTER (middle key) is used to complete a command sequence. Trackball SELECT (left key) is used to identify an item for modification in the message composition (MC) view and to identify lists for moving them on the display.

- Data as shown in a display or entered on the keyboard are presented in quotation marks. When spaces are required, they are included within the quotation marks. The quotation marks are not part of the display or entry.

- All spaces included within quotation marks for keyboard entries are mandatory. For example, "DL S " *should be interpreted as typing DL followed by a space, and S followed by a space.*

- FLID refers to any NAS command for identifying a flight including:

  . The Aircraft Identification Call Sign (AID)

  . The Computer Identification Number (CID)

  . The Beacon Code

  . Positioning the trackball cursor over the data block and pressing trackball ENTER

DATA LINK FULL DATA BLOCK DISPLAYS AND STATUS LIST

- Function

The Full Data Block (FDB) provides unique graphic characters which indicate that an aircraft is equipped to receive Data Link messages, and whether the observing control position is eligible to uplink messages to the aircraft. The FDB also provides information about the status of an ongoing Data Link transaction.

The status list is an ISSS view which contains information about the content and current status of ongoing Data Link transactions.

- Full Data Block Equipage and Eligibility Indicators

Data Link equipage and eligibility are indicated by graphic characters located in the first position of the first line of the FDB. No special character in this position identifies an aircraft that is not capable of communicating via Data Link. An open diamond ( ) indicates that the aircraft is Data Link equipped, but that the viewing sector position is ineligible to communicate with it. A filled diamond ( ) indicates that the aircraft is equipped and that the viewing sector is eligible.

- Status List Line Content

The status list is identified by "DLSL" displayed in the header area of the view. Each line of the list contains information about one ongoing transaction. A line has four data fields displaying 1) the aircraft identification, 2) a two-letter abbreviation for the Data Link service or function, 3) up to eight characters indicating the content of the uplinked message, and 4) a three-letter abbreviation for the status of the transaction. For example, "UA123 AA 300 SNT" would indicate that the controller had uplinked an altitude assignment of 30,000 feet to UA123 and that the message is in the sent status.

- Status List Abbreviations for Data Link Services

The second field of a status line presents one the following two-character abbreviations to indicate the type of message in progress:

"TC" - Transfer of Communication

"AA" - Altitude Assignment

"IA" - Interim Altitude

"MT" - Menu Text

"FT" - Communication Backup (Free Text)

- Status List Abbreviations of Transaction Status

The fourth field of a status line presents the following three-character abbreviations to indicate the current status of the transaction:

"SNT" - Sent - A controller input or system event has initiated the uplink

"HLD" - Held - A message containing the radio frequency of a new airspace sector which the aircraft will enter has been prepared and is ready for uplink when the sending controller makes an appropriate input. "HLD" is displayed in yellow to indicate a routine required controller action.

"WIL" - Wilco - The system has received a downlink from the flight deck indicating that the pilot has received the the uplinked message and intends to comply with the command or clearance.

"UNB" - Unable - The system has received a downlink from the flight deck indicating that the pilot has received the the uplinked message, but is unable to comply with the command or clearance. "UNB" is displayed in yellow to alert the controller.

"STB" - Standby - The system has received a downlink from the flight deck indicating that the pilot has received the the uplinked message, but requires additional time to evaluate the message and send a wilco or unable response. STB" is displayed in yellow to alert the controller.

"TIM" - Time Out - A timer initiated when the uplinked message was sent has expired. For testing purposes, this adaptable time parameter is set to 40 seconds. The time out message is an indication to the controller of an unusually lengthy delay for receipt of a response from the aircraft. "TIM" is displayed in yellow to alert the controller.

- Full Data Block Indications for Data Link Services and Transaction Status

FDB status and content indicators are correlated with the status list indicators, but vary depending upon the service involved.
They are described in detail under succeeding sections devoted to each service.

- Inputs to Move the Status List

The status list view can be moved to any position on the display by typing "M", positioning the cursor in the header area of the status list and pressing the trackball SELECT key, repositioning the list, and pressing the trackball ENTER key.

- Inputs to Suppress or Retrieve the Status List

The status list view can be suppressed by typing "SU", positioning the trackball cursor in the header area of the status list, and pressing the trackball ENTER key. An icon located over the upper left corner of the suppressed list indicates its position. Typing "SU", positioning the cursor over the icon and pressing the trackball ENTER key will unsuppress (display) the status list.

ENTRY ERROR MESSAGES

In addition to other ISSS controller input error messages, the following Data Link error messages may appear in the Message Composition (MC) view:

- "NOT DL ELIGIBLE FOR SECTOR"

This message will appear if the controller attempts to send a Data Link message to an equipped aircraft with which the controller is ineligible for communication (open diamond shown in first position of first FDB line as displayed at the controller's sector).

- "NO DATA LINK"

This message will appear if the controller attempts to send a Data Link message to a non-equipped aircraft (no symbol shown in first position of first FDB line as displayed at the controller's sector).

- "MAX NO. OF AA EXCEEDED"
  TC

This message will appear if the controller attempts to send a second altitude (AA) or transfer of communication (TC) message to an aircraft that currently has one of the same type of transaction open.

- "DATA LINK NOT ENABLED"

This message will appear if the controller attempts to send an uplink when Data Link processing is turned off for the sector.

- "TRANSACTION ACTIVE FOR SERVICE"

This message will appear if, while a Data Link transaction remains open, the controller attempts to: 1) transfer Data Link eligibility to another sector, 2) handoff an aircraft, 3) amend an altitude or 4) uplink a menu text altitude message. This message also will be returned if the controller attempts to send a backup communication (FT) message when three other backup transactions to that aircraft are open.

- "INVALID STATUS FOR DELETION"

This message will appear if the controller attempts to delete a Data Link transaction that has a status other than, HELD, UNABLE, or TIME OUT.

- "MT NO VALID DATA"

This message will appear if the controller attempts to change the content of a menu text message which does not have a variable altitude value field.

TRANSFER OF COMMUNICATION

- Function

The Data Link transfer of communication message is automatically prepared when the receiving controller accepts a sector handoff for an equipped aircraft. The sending controller has the option to send the new frequency automatically when the handoff is accepted, or to send the message manually at a later time.

- Inputs to Set the Transfer of Communication Mode

Transfer of communication can be set to the automatic mode by typing "DP A". The manual mode is set by typing "DP M".

If the USER DFBL soft function set has been selected, pressing F8 will substitute for typing "DP A" and pressing F9 will substitute for typing "DP M".

- Manual and Automatic Send Inputs

When in the automatic mode, the transfer of communication message will be uplinked with no additional action by the sending controller when the receiving sector accepts the handoff.

When in the manual mode, acceptance of the handoff will place the prepared message in a held status. The message is sent by the controller by slewing to the appropriate line in the status list and pressing the trackball ENTER.

- Status List and Full Data Block Displays on Transfer of Communication

The status list entry for a transfer of communication transaction presents the AID, the two letter abbreviation "TC", the receiving sector's frequency, and the current transaction status message. When in a manual mode, the "HLD" status message is displayed in yellow until the controller completes the slew action to send the message. In the automatic mode, the status line appears in the "SNT" state immediately after acceptance of the handoff.

In either mode of operation, when the transfer of communication message is sent, an up-arrow symbol replaces the Data Link equipage/eligibility indicator in the first position of the first line of the FDB that is displayed to the sending and receiving sectors. When the wilco is received from the flight deck, the up-arrow is replaced by the filled diamond in the receiving sector and by the open diamond in the sending sector.

- Unable and Time Out Displays for Transfer of Communication and Controller Responses.

If the flight deck responds to a transfer of communication message with an unable, "UNB" is displayed in yellow in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds, "TIM" is displayed in yellow in the status field.

The unable or time out conditions also will cause the up-arrow in the first position of the first line of the sending controller's FDB to revert to the filled diamond symbol indicating that Data Link eligibility remains at the sending sector. However, the filled diamond will be yellow rather than white to alert the controller.

The controller can close the transaction and delete all "UNB" or "TIM" indicators by typing "D" positioning the cursor over the status list entry, and pressing the trackball ENTER key. Alternatively, the controller may type "D TC " and the FLID; or "D ", the sequential number of the line in the status list (counting from the top of the list), and " V/DLSL". Thus, "D 3 V/DLSL would delete the transaction on the third line of the list.

- Sending an Automatic Transfer of Communication When in Manual Mode

While working in the manual mode, the controller can selectively choose to send the message automatically to individual aircraft by adding a single keystroke to the normal sequence used to offer a handoff. The transfer of communication message will be sent automatically upon handoff acceptance if the controller offers the handoff by typing "HO ", the two digit receiving sector number, " S ", and one or more FLIDs separated by spaces (e.g. "HO 22 S US435). Note:"HO" is an optional input. Adding the "S" to a single handoff command will not affect other subsequent aircraft handoffs, and the default mode will remain manual.

- Forcing Data Link Eligibility to a Sector

A sector that has Data Link eligibility can transfer it to a new sector without completion of a handoff by typing "DL " the two digit receiving sector number followed by a space, and one or more FLIDs separated by spaces (e.g. "DL 22 UA765").

To simultaneously force eligibility and send the new sector frequency to the flight deck, insert " S " after the sector number (e.g. "DL 22 S UA765").

In the above commands, if the USER DFBL soft function set has been selected, pressing F1 will substitute for typing "DL".

- "Stealing" Data Link Eligibility from a Sector

Data Link eligibility can be acquired from another sector in the absence of a completed handoff by typing "DL /OK " followed by one or more FLIDs separated by spaces.

To simultaneously acquire eligibility and send your sector frequency to the flight deck, insert " S " after the /OK (e.g.
"DL /OK S US221".

In either command, if the USER DFBL soft function set is selected pressing F2 will substitute for typing "DL /OK".

- "Stealing" Data Link Eligibility from a Sector and Forcing to Another Sector

Sector A can acquire eligibility from sector B and force it to sector C by typing "DL /OK " the two digit number of sector C, and one or more FLIDs separated by spaces. Thus, if the controller at sector A typed "DL /OK 21 AA534", AA534 Data Link eligibility would be taken from sector B and forced to sector 21 (sector C).

To simultaneously complete the transfer and send sector C's frequency to the flight deck, insert " S " after the sector number (e.g. "DL /OK 21 S AA534").

In either command, if the USER DFBL soft function set has been selected, pressing F2 will substitute for typing "DL /OK".

ALTITUDE ASSIGNMENT - MANUAL ENTRY

- Function

This service permits the controller to uplink an altitude assignment or an interim altitude by manually entering a three digit altitude value (hundreds of feet). A message that receives a wilco downlink from the flight deck automatically updates the the NAS database and/or the FDB, as appropriate.

- Inputs to Send an Altitude Assignment

To update the NAS database when an altitude is assigned by voice radio the ISSS Amend command is used. This is achieved by typing "AM ALT ", three digits indicating the altitude in hundreds of feet, and a space followed by the FLID. The "AM ALT " portion of the command is optional.

To update the system and send the message by Data Link, an "S" is inserted between the altitude value and the FLID
(e.g. "AM ALT 300 S UA123" keyboard ENTER or "300 S" slew to aircraft FDB, trackball ENTER)

- Full Data Block and Status List Displays on Altitude Uplink

When the assigned altitude send command is entered, the new altitude value followed by an "S" appears in the first four positions of the second line of the FDB. This timeshares with the display of the previous assigned altitude and conformance indicator.

Upon receipt of a wilco response from the flight deck, the "S" is replaced by a "W". The timesharing continues for six seconds, after which the new assigned altitude is shown with the appropriate conformance indicator.

During the transaction, the status list displays the AID, the "AA" message type abbreviation, the altitude value and the current status abbreviation. Upon receipt of a wilco, "WIL" is displayed for six seconds, after which the entire status list line is automatically deleted.

- Inputs to Send an Interim Altitude

To update the data block when an interim altitude sent by voice radio the ISSS Amend command is used. This is achieved by typing "AM T ", three digits indicating the altitude in hundreds of feet, and a space followed by the FLID. The "AM" portion of the command is optional.

To update the FDB and send the message by Data Link, an "S" is inserted between the altitude value and the FLID
(e.g. "AM T 100 S UA123" keyboard ENTER or "T 100 S" slew to aircraft FDB, trackball ENTER)

- Full Data Block and Status List Displays on Interim Altitude Uplink

When the interim altitude send command is entered, the interim altitude value followed by an "S" appears in the first two fields of the second line of the FDB. This timeshares with the display of the current assigned altitude and conformance indicator. Upon receipt of a wilco response from the flight deck, the "S" is replaced by a "W". The timesharing continues for six seconds, after which the accepted interim altitude is shown with the normal "T" conformance indicator.

During the transaction, the status list displays the AID, the "IA" message type abbreviation, the interim altitude value and the current status abbreviation. Upon receipt of a wilco, "WIL" is displayed for six seconds, after which the entire status list line is automatically deleted.

- Unable and Time Out Displays for Assigned and Interim Altitudes and Controller Responses.

If the flight deck responds to an altitude clearance with an unable, "UNB" is displayed in yellow in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds, "TIM" is displayed in yellow in the status field. In the FDB, "UNB" or "TIM" is displayed in yellow in the last three positions of the second line to indicate these failure conditions.

In either case, the controller can close the transaction and delete all "UNB" or "TIM" indicators by typing "D" positioning the cursor over the status list entry, and pressing the trackball ENTER key. Alternatively, the controller may type "D ","AA " or "IA ", and the FLID; or "D ", the sequential number of the line in the status list (counting from the top of the list), and " V/DLSL". Thus, "D 3 V/DLSL" would delete the transaction on the third line of the list.

INITIAL CONTACT

- Function

This service substitutes the initial radio call from the flight deck after a transfer of communication with a downlink report of assigned altitude. Under normal conditions, the initial contact procedure is automatic and transparent, and requires no controller interaction.

- Initial Contact Procedure

An altitude request message is automatically appended to the radio frequency assignment message that is uplinked during transfer of communication. The flight deck responds to the transfer of communication uplink by downlinking a wilco along with a report of assigned altitude to the sending controller.

Receipt of the wilco response transfers Data Link eligibility to the receiving sector. In addition, the reported assigned altitude is automatically checked against the aircraft's assigned altitude recorded in the NAS data base. If the aircraft's reported assigned altitude matches the data base value, nothing is displayed at the sending or receiving sectors, and no additional controller action is required.

- Flight Deck Failure to Append Reported Altitude

If the flight crew fails to append the altitude report to the transfer of communication wilco, a no altitude ("NALT") message is displayed in the first four positions of the second line of the FDB at both the sending and receiving controllers' display. "NALT" is displayed in yellow to alert the controllers.

The Data Link eligible receiving controller with track control may respond by contacting the flight deck via voice radio, and can clear the "NALT" display by slewing to the FDB, or by updating the aircraft's assigned or interim altitude, with or without an uplink to the flight deck.

- Discrepancy Between Reported and Flight Plan Assigned Altitudes

If the reported assigned altitude fails to match the assigned altitude contained in the NAS data base, the downlinked value and the data base values followed by "E" timeshare in the first four positions of the second line of the FDB. This display is presented in yellow to alert the controllers.

The Data Link eligible receiving controller with track control may respond by contacting the flight deck via voice radio, and can clear the error display by slewing to the FDB, or by updating the aircraft's assigned or interim altitude, with or without an uplink to the flight deck.

MENU TEXT

- Function

The Menu Text function permits the controller to uplink frequently used messages by selecting them from a predefined menu view. Currently, these messages include altitude assignments, interim altitudes with fix crossing restrictions, and text messages. Menus can be tailored to meet the specific requirements of individual airspace sectors.

- Menu Format

The menu is an ISSS view identified by "DLMT" in the header area. Each line of the menu contains one message preceded by an identifying letter used to select the message. Altitude messages are preceded by QZ or QQ to indicate whether the clearance is an altitude assignment or an interim altitude. Some sample messages are shown below:

A QZ CLIMB AND MAINTAIN FL 230
B QQ CROSS BUZZY @ 110
C QZ DESCEND AND MAINTAIN FL 100
D CALL COMPANY

- Inputs to Send a Menu Text Message

To send a menu text message (and update the NAS data base/FDB when appropriate) type "DL " the menu item identifier followed by a space, one or more FLIDs and ENTER. The message can be sent to multiple aircraft by adding additional FLIDs prior to pressing ENTER (e.g. "DL D AA123 UA321").

To send a message using only the trackball, slew to the desired menu item and press the trackball ENTER key, and then SLEW to the FDB and press the trackball ENTER key.

- Full Data Block and Status List Displays on Menu Text Uplink

If the uplinked menu item is an altitude assignment or an interim altitude, the FDB content and status displays will be identical to those described for manually entered altitude clearances. No FDB display is provided if the menu item is a text message.

For all messages sent from the menu, the status list will display the AID followed by "MT", the menu item identifier, and the current status of the transaction (e.g. "AA231 MT A SNT"). The actual content of the message can be reviewed by referring to the indicated item identifier in the menu.

- Unable and Time Out Displays for Menu Text and Controller Responses.

FDB and status list displays for these failure conditions for menu text altitude messages are identical to those provided for manually entered assigned and interim altitudes. If the flight deck responds to a menu text altitude clearance with an unable, "UNB" is displayed in yellow in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds, "TIM" is displayed in yellow in the status field. In the FDB, "UNB" or "TIM" is displayed in yellow in the last three positions of the second line to indicate these failure conditions.

Unable and time out displays for text messages in the menu are presented only in the status list. If the flight deck responds to a communications back up message with an unable, "UNB" is displayed in yellow in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds, "TIM" is displayed in yellow in the status field.

The controller can close any menu text transaction and delete all "UNB" or "TIM" indicators by typing "D" positioning the cursor over the status list entry, and pressing the trackball ENTER key. Alternatively, the controller may type "D ", the sequential number of the line in the status list (counting from the top of the list), and " V/DLSL". Thus, "D 3 V/DLSL" would delete the transaction on the third line of the list.

- Special Menu Text Items (R and Z)

Two menu item identifiers are reserved for special altitude uplinks. Selecting item "R" when included in a menu will uplink the aircraft's requested altitude. Selecting item "Z" when included in a menu will uplink the aircraft's assigned altitude.

(note: these items are not supported in the current simulation)

- Modifying Menu Text Altitude Item Content

A complete menu build function will be used by supervisory personnel to create sector-tailored menus. However, it is expected that controllers will have some latitude to modify menu content on an as-needed basis.

To change the altitude value in an existing menu item, type "DP MC " the menu item identifier followed by a space and the new altitude value (e.g. DP MC A 100). This action will change the displayed data in the selected menu item. The new data will be sent in subsequent uplinks of the item until another value is entered using the same command.

If the USER DFBL soft function set has been selected, pressing F5 will substitute for typing "DP MC" in the command.

To return all modified altitude values in the menu to their preadapted default values, type "DP MD" or, when the USER DFBL soft function key set has been selected, press F6.

- Temporarily Modifying Menu Text Altitude Items

To make a one-time change to an altitude in a menu text item and send it to an aircraft, slew to the desired menu text item and press the trackball SELECT key. This will place the item in the common console Message Composition (MC) view. Type the substitute replacement altitude followed by a space and the FLID. This series of actions will send the modified message to the selected aircraft, but leave the original message in the menu unchanged for future uplinks.

The temporary altitude change will not appear in the menu or the status list. However, during the transaction, the data block display of the uplink will reflect the new value timesharing with the current assigned altitude.

- Inputs to Move the Menu

The menu view can be moved to any position on the display by typing "M", positioning the cursor in the header area of the menu and pressing the trackball SELECT key, repositioning the menu with the trackball, and pressing the trackball ENTER key.

- Inputs to Suppress or Display the Menu

The menu view can be suppressed by typing "SU", positioning the trackball cursor in the header area of the menu, and pressing the trackball ENTER key. An icon located over the upper left corner of the suppressed menu indicates its position. Typing "SU", positioning the cursor over the icon and pressing the trackball ENTER key will unsuppress (display) the menu.

If the USER DFBL soft function set has been selected, pressing F7 will substitute for typing "SU".

COMMUNICATIONS BACKUP

- Function

The communications backup service permits the controller to compose and send any free text message using Data Link. Unlike the other Data Link services in which only one transaction for each service type can be simultaneously in process with an aircraft, up to three communications backup messages can be open with a single aircraft.

- Inputs to Send a Communications Backup Message

To uplink a text message type "DL T " a message up to 20 characters in length followed by a space, and a FLID (e.g. "DL T CHECK FOR STUCK MIC AA123"). The FLID can be replaced by "ALL" to uplink the message to all eligible aircraft in the sector.

If the USER DFBL soft function set is selected, pressing F3 will substitute for "DL T" in the command.

- Full Data Block and Status List Displays on Communications Backup Uplink

No FDB display is provided for this service. During the transaction, the status list displays the AID, the "FT" message type abbreviation, the first six characters of the text message, and the current status abbreviation. Upon receipt of a wilco, "WIL" is displayed for six seconds, after which the entire status list line is automatically deleted.

- Unable and Time Out Displays for Communications Backup and Controller Responses.

If the flight deck responds to a communications backup message with an unable, "UNB" is displayed in yellow in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds, "TIM" is displayed in yellow in the status field. No FDB display of these failure conditions is provided.

In either case, the controller can close the transaction and delete all "UNB" or "TIM" indicators by typing "D" positioning the cursor over the status list entry, and pressing the trackball ENTER key. Alternatively, the controller may type "D FT " and the FLID, or "D ", the sequential number of the line in the status list (counting from the top of the list), and " V/DLSL". Thus, "D 3 V/DLSL" would delete the transaction on the third line of the list.

APPENDIX B

AIRSPACE TRAINING PACKAGE

LOCATION IDENTIFIERS
ALL SECTORS

VORs/VORTACs

AVE = Avenal
BSR = Big Sur
CZQ = Clovis
ECA = Manteca

ENI = Mendocino
LIN = Linden
MOD= Modesto
MQO= Morrow Bay

OAK = Oakland
OSI = Woodside
PYE = Point Reyes
RBL = Red Bluff

SAC = Sacramento
SAU = Sausalito
SFO = San Francisco
SNS = Salinas

INTERSECTIONS

ALCOA	BEBOP	BLATZ	BLUFF
BOLDR	BRINY	CEDES	CLUKK
DAANN	LOZIT	PIRAT	SKUNK
STINS	WAGES		

SECTOR 12

VORs/VORTACs

AVE = Avenal
BSR = Big Sur
CZQ = Clovis
MQO= Morrow Bay
OAK = Oakland
OSI = Woodside
SFO = San Francisco
SNS = Salinas

INTERSECTIONS

BOLDR SKUNK WAGES

SECTOR 24/17

VORs/VORTACs

ECA = Manteca
ENI = Mendocino
LIN = Linden
MOD= Modesto
OAK = Oakland
SAC = Sacramento
SFO = San Francisco

INTERSECTIONS

CEDES

SECTOR 35

VORs/VORTACs

MQO= Morrow Bay
OAK = Oakland
OSI = Woodside
SFO = San Francisco

INTERSECTIONS

ALCOA	BEBOP	BLATZ	BLUFF
BRINY	CLUKK	DAANN	PIRAT

SECTOR 41

VORs/VORTACs

ECA = Manteca
ENI = Mendocino
OAK = Oakland
PYE = Point Reyes
RBL = Red Bluff
SAU = Sausalito
SFO = San Francisco

INTERSECTIONS

LOZIT
STINS

OAKLAND ARTCC
AND
BAY TRACON

LETTER
OF
AGREEMENT

EFFECTIVE: December 1, 1993

SUBJECT: Terminal Area Control

PURPOSE: Establish procedures for the coordination and control of air traffic between BAY TRACON and Oakland ARTCC.

PROCEDURES:

General:

- Aircraft shall be routed via preferred departure and arrival routes as specified in this letter of agreement.
- Similar performance arrivals or departures routed via the same fix shall be sequenced in-trail.

- The minimum separation provided by the CENTER shall be 5 miles constant or increasing.

- The minimum separation provided by the TRACON shall be 7 miles constant or increasing, 3 miles **constantly increasing** may be provided to the CENTER on departures. The first center controller shall ensure the aircraft are provided standard CENTER separation before exiting the first CENTER sector.

- TRACON releases aircraft for turns of up to 30 degrees.

- CENTER releases aircraft for turns of up to 30 degrees.

- The Transfer Control Point (TCP) shall be the vertical extension of the lateral limits of TRACON airspace.

ARRIVALS TO: SOUTH FEEDER from SECTOR 12.

JETS:

cleared via: **BSR..SKUNK..BOLDR..SF0**

and cross: **BOLDR INTERSECTION**

at: **10,000 feet** and **250 knots**

PROPS

cleared via: **BSR..OSI..SFO**

and cross: **20 miles S of OSI**

at: **8,000 feet**

ARRIVALS TO: SOUTH FEEDER FROM SECTOR 35

JETS:

cleared via: **BRINY..OSI..SFO**

and cross: **20 miles W of OSI**

at: **8,000 feet** and **250 knots**

PROPS:

cleared via: **BRINY..OSI..SFO**

and cross: **20 miles W of OSI**

at: **8,000 feet**

ARRIVALS TO: NORTH FEEDER from SECTOR 17/24

JETS:

cleared via: **CEDES..SFO**

to cross: **CEDES**

at: **11,000 feet** and **250 knots**

PROPS:

cleared via: **CEDES..SFO**

to cross: **CEDES**

at: **10,000 feet**

ARRIVALS TO: NORTH FEEDER from SECTOR 40/41

JETS:

cleared via: **LOZIT..SFO**

to cross: **LOZIT INTERSECTION** (22 MILES NW SFO)

at: **11,000 feet** and **250 knots**

PROPS:

cleared via: **PYE..HADLY..OSI..SFO**

to cross: **16 miles SE of PYE** (STINS INTERSECTION)

at: **9,000 feet** or **7,000 feet**

DEPARTURES FROM : SUTRO -DR1 TO SECTOR 12

JETS:

cleared via:

AS FILED

climbing to:

FL230

(or lower if requested)

PROPS:

cleared via:

AS FILED

climbing to:

11,000 feet

(or lower if requested)

DEPARTURES FROM: SUTRO - DR1 to SECTOR 35

JETS

cleared via:

AS FILED

climbing to:

10,000 feet (center control to climb)

PROPS:

cleared via:

AS FILED

climbing to:

10,000 feet

(or lower if requested)

DEPARTURES FROM: RICHMON to SECTOR 17/24

JETS:

cleared via:

AS FILED

climbing to:

FL230

(or lower if requested)

PROPS:

cleared via:

AS FILED

climbing to:

11,000 feet

(or lower, center control for climb)

OAKLAND CENTER

SECTOR 12

STANDARD OPERATING PROCEDURES

Assignment of Airspace

- Sector Boundaries
- Sector Graphic Chart

Operation of Equipment

- Equipment Preparation
- Radar Settings

Control Procedures

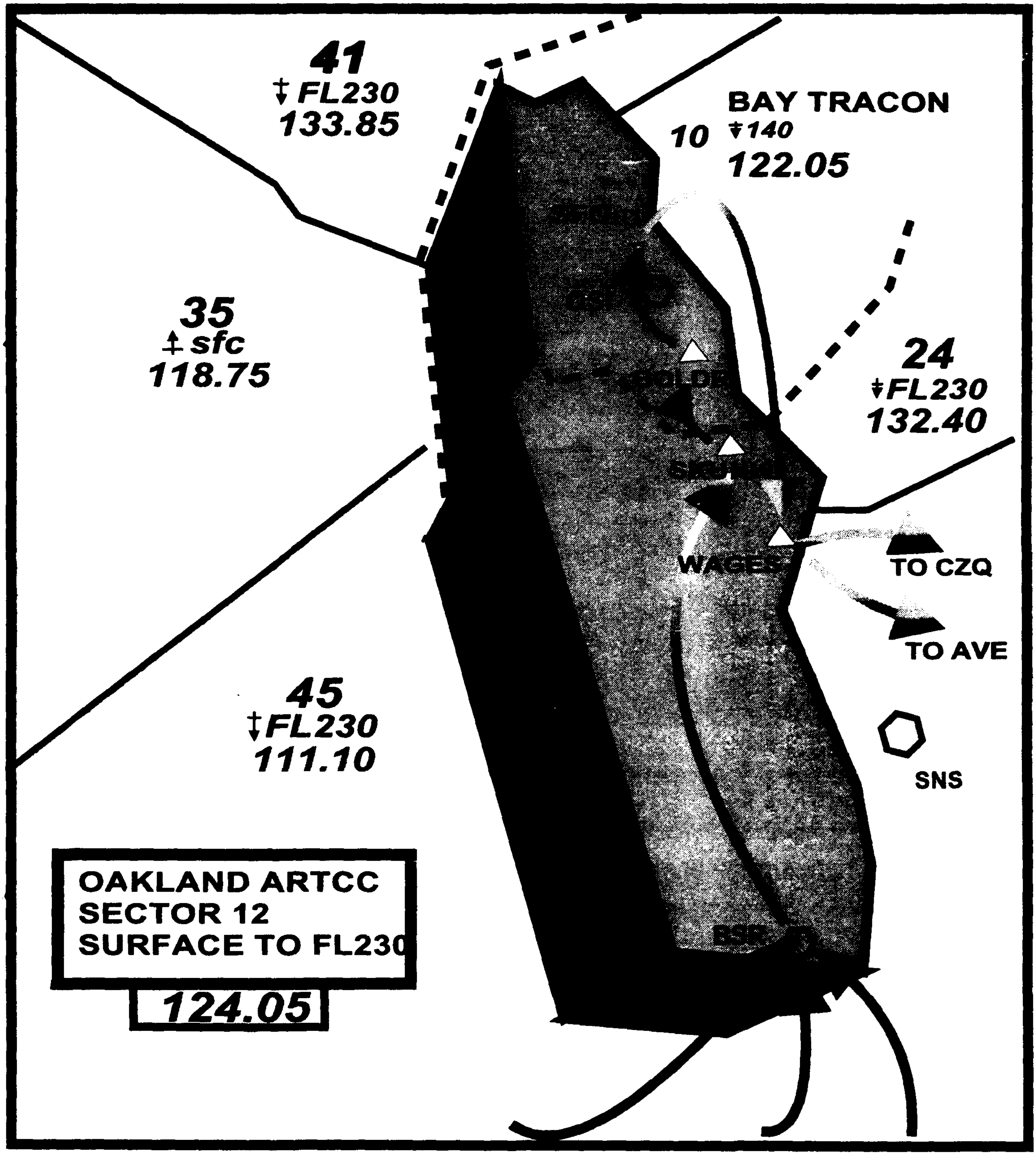
- Speed Restrictions
- Vectoring
- Sequencing
- Arrival Procedures
- Departure Procedures
- Point-out Procedures
- Holding

Flight Plan Information

- Sequencing Flight Progress Strips
- Non-Radar Oceanic Coordination

ASSIGNMENT OF AIRSPACE

Except for BAY TRACON Airspace, Sector 12 has jurisdiction within the boundaries depicted, at FL230 and BELOW.



EQUIPMENT PREPARATION

Video maps available to Sector 12:

MAP 1 - Navaids and intersections

MAP 2 - Airways and Sector Boundaries

MAP 3 - High Altitude Sector Boundaries

MAP 4 - Special Areas

MAP 5 - E-MSAW

RADAR SETTINGS

RANGE:	60 miles
FILTER KEYS SELECTED:	WX1, WX2, MAP1, MAP2, FDB, ALL PRIMARIES, SEL BCN, NON MODE C, ALT1 through ALT5. (other filter keys optional)
ALTIMITER SETTINGS:	SFO
ALTITUDE LIMITS:	000B242

MANDATORY SPEED RESTRICTIONS

BAY TRACON ARRIVALS:

Jets shall cross BOLDR intersection (34 miles SE of OAK) at 10,000 feet and 250 knots.

SEQUENCING

Sequence BAY TRACON arrivals from the south cleared to BAY TRACON via BSR..SKUNK..BOLDR..SFO. Aircraft operating above FL240 shall be cleared to FL240 by the previous sector.

* BSR = BIG SUR VORTAC

ARRIVAL PROCEDURES

BAY TRACON AIRPORTS:

JET ARRIVALS

cleared via:

BSR..SKUNK..BOLDR..SFO

and cross:

BOLDR INTERSECTION

at:

10,000 feet
and
250 knots

*BOLDR=OAK151034

PROP ARRIVALS

cleared via:

BSR..OSI..SFO

and cross:

20 MILES S of OSI

at:

8,000 feet

NOTE: High performance turboprops (E120,SW3, etc.) may be cleared via the jet procedures at controller's discretion.

* OSI = WOODSIDE VOTAC

DEPARTURE PROCEDURES

BAY TRACON AIRPORTS:

JETS are cleared as filed, climbing to FL230, or lower altitude if requested. Oakland ARTCC has control for turns.

PROPS are cleared as filed, climbing to11,000 feet, or lower altitude if requested, and are sector 12's control for climb. Oakland ARTCC has control for turns.

When traffic permits, a temporary altitude of FL230 should be entered into the data-block of all aircraft requesting FL240 or above, and a hand-off should be made to the overlying sector. (see **Altitude Coord.**)

When traffic does not permit a climb to FL230, climb the aircraft to the highest available altitude in your airspace, and execute a hand-off to the adjoining sector.

POINT OUT PROCEDURES

Whether or not the handoff has been accepted, the transferring controller shall make all necessary point outs within the same altitude stratum (low to low or high to high) unless otherwise coordinated.

HOLDING

SKUNK (published)

Hold SE of SKUNK on the OAK151 radial.
Left turns
Standard leg
Min. altitude 5,000 feet
Max. altitude FL450

FLIGHT PLAN INFORMATION

SEQUENCING FLIGHT PROGRESS STRIPS

3 Suggested Bayheaders:

ACTIVE:	Used for active flight plans.
PROPOSAL:	Proposal bay for all departures or pop-ups.
SECTOR 12:	Bay for pending strips.

NONRADAR/OCEANIC COORDINATION

The next sector/facility will have all necessary information on nonradar/oceanic flights. Acceptance of track control shall constitute approval to enter the next sector's or facility's airspace.

ALTITUDE COORDINATION

Acceptance of a hand-off by the next center sector, of an aircraft with a temporary altitude in the data block, shall constitute approval of that altitude.

AVE = Avenal VORTAC
BSR = Big Sur VORTAC
CZQ = Fresno VORTAC
OAK = Oakland VORTAC/Airport
OSI = Woodside VORTAC
SFO = San Fransisco VORTAC/Airport
SNS = Salinas VORTAC

OAKLAND CENTER

SECTOR 17/24

STANDARD OPERATING PROCEDURES

Assignment of Airspace
- Sector Boundaries
- Sector Graphic Chart

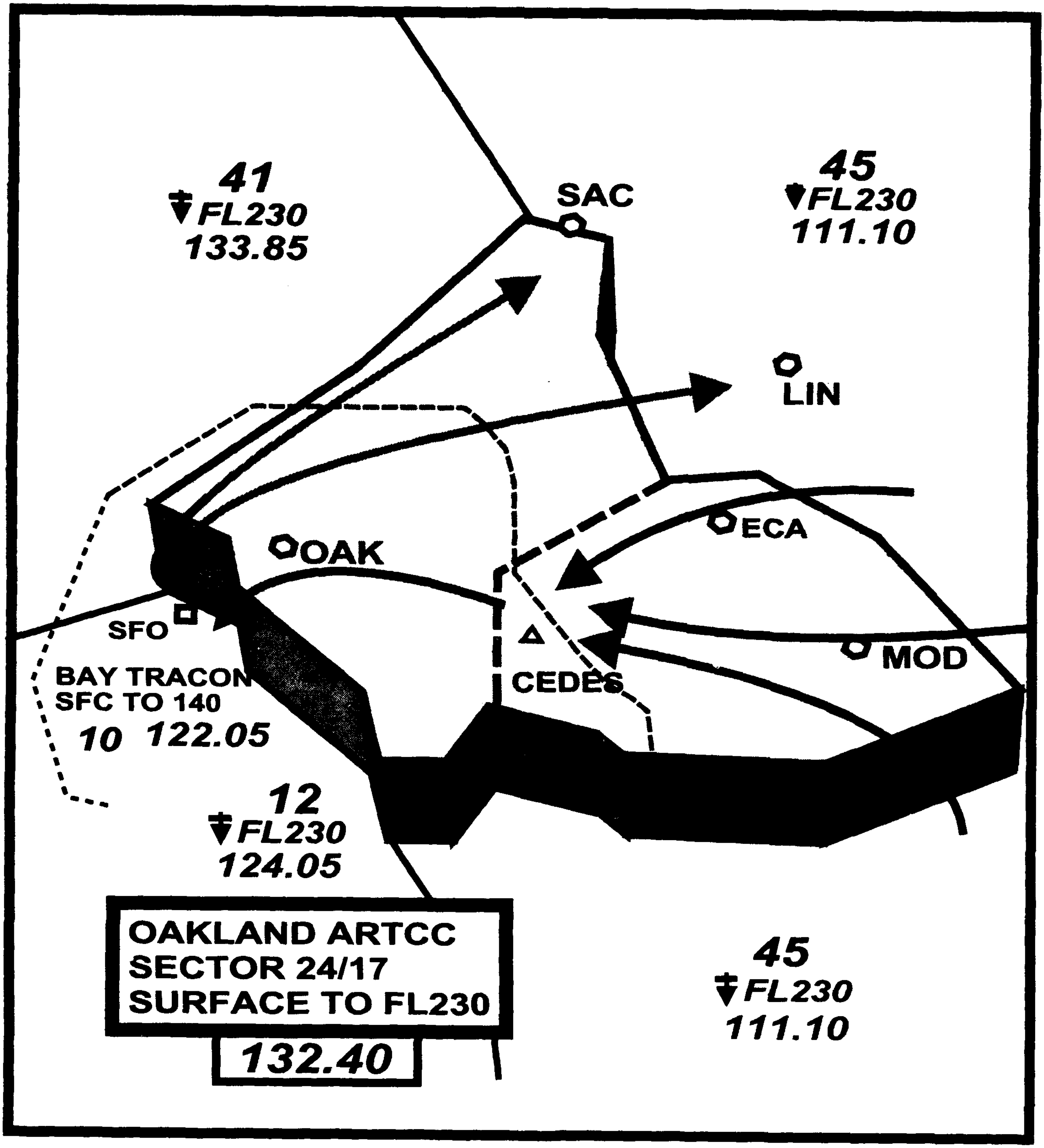
Operation of Equipment
- Equipment Preparation
- Radar Settings

Control Procedures
- Speed Restrictions
- Vectoring
- Sequencing
- Arrival Procedures
- Departure Procedures
- Point-out Procedures
- Holding

Flight Plan Information
- Sequencing Flight Progress Strips
- Non-Radar Oceanic Coordination
- Altitude Coordination

ASSIGNMENT OF AIRSPACE

Except for BAY TRACON airspace, Sector 24/17 has jurisdiction within the boundaries depicted, at FL230 and BELOW.



EQUIPMENT PREPARATION

Video maps available to Sector 17/24:

MAP 1 - Navaids and intersections

MAP 2 - Sector Boundaries

MAP 3 - High Altitude Sector Boundaries

MAP 4 - Special Areas

MAP 5 - E-MSAW

RADAR SETTINGS

RANGE:	190
FILTER KEYS SELECTED:	WX1, WX2, MAP1, MAP2, FDB, ALL PRIMARIES, SEL BCN, NON MODE C, ALT1 through ALT5. (other filter keys optional)
ALTIMITER SETTINGS:	SFO, OAK
ALTITUDE LIMITS:	000B242

MANDATORY SPEED RESTRICTIONS

BAY TRACON ARRIVALS:

Jets shall cross CEDES intersection (32 miles SW of MOD) at 11,000 feet and 250 knots.

(MOD = Modesto VOR/DME)

SEQUENCING

Sequence BAY TRACON arrivals from the east cleared into BAY TRACON via CEDES..SFO. Aircraft operating above 16,000 feet shall be descended to 16,000 feet by the previous sector, unless otherwise coordinated. Acceptance of a handoff with other than 16,000 feet displayed in the temporary altitude shall be considered coordination.

ARRIVAL PROCEDURES

BAY TRACON AIRPORTS:

JET ARRIVALS

cleared via:

CEDES..SFO

and cross:

CEDES INTERSECTION

at:

11,000 feet
and
250 knots

*CEDES = MOD245032

PROP ARRIVALS

cleared via:

CEDES..SFO

and cross:

CEDES

at:

10,000 feet

NOTE: High performance turboprops (E120,SW3, etc.) may be cleared via the jet procedures at controller's discretion.

DEPARTURE PROCEDURES

BAY TRACON AIRPORTS:

JETS are cleared as filed, climbing to FL230, or lower altitude if requested. Oakland ARTCC has control for turns.

PROPS are cleared as filed, climbing to 11,000 feet, or lower altitude if requested. Oakland ARTCC has control for turns and climb.

When traffic permits, a temporary altitude of FL230 should be entered into the data-block of all aircraft requesting FL240 or above, and a hand-off should be made to the overlying sector. (see **Altitude Coord**.)

When traffic does not permit a climb to FL230, climb the aircraft to the highest available altitude in your airspace, and execute a hand-off to the adjoining sector.

POINT OUT PROCEDURES

Whether or not the handoff has been accepted, the transferring controller shall make all necessary point outs within the same altitude stratum (low to low or high to high) unless otherwise coordinated.

HOLDING

CEDES (published)

Hold SE of CEDES on the MOD 245 radial.
Left turns
Standard leg
Min. altitude 5,000 feet
Max. altitude FL450

FLIGHT PLAN INFORMATION

SEQUENCING FLIGHT PROGRESS STRIPS

4 Suggested Bayheaders:

ARRIVALS:	Used for arrival flight plans.
DEPARTURES:	Used fo departure flight plans.
PROPOSAL:	Proposal bay for all departures or pop-ups.
SECTOR 17/24:	Used for all other flight plans.

NONRADAR/OCEANIC COORDINATION

The next sector/facility will have all necessary information on nonradar/oceanic flights. Acceptance of track control shall constitute approval to enter the next sector's or facility's airspace.

ALTITUDE COORDINATION

Acceptance of a hand-off by the next center sector, of an aircraft with a temporary altitude in the data block, shall constitute approval of that altitude.

<u>**VORTACs**</u>

OAK = Oakland
SAC = Sacramento
ECA = Manteca
LIN = Linden
ENI = Mendocino

<u>**VOR/DMEs**</u>

MOD = Modesto
SFO = San Francisco

OAKLAND CENTER

Sector 35

STANDARD OPERATING PROCEDURES

Assignment of Airspace
- Sector Boundaries
- Sector Graphic Chart

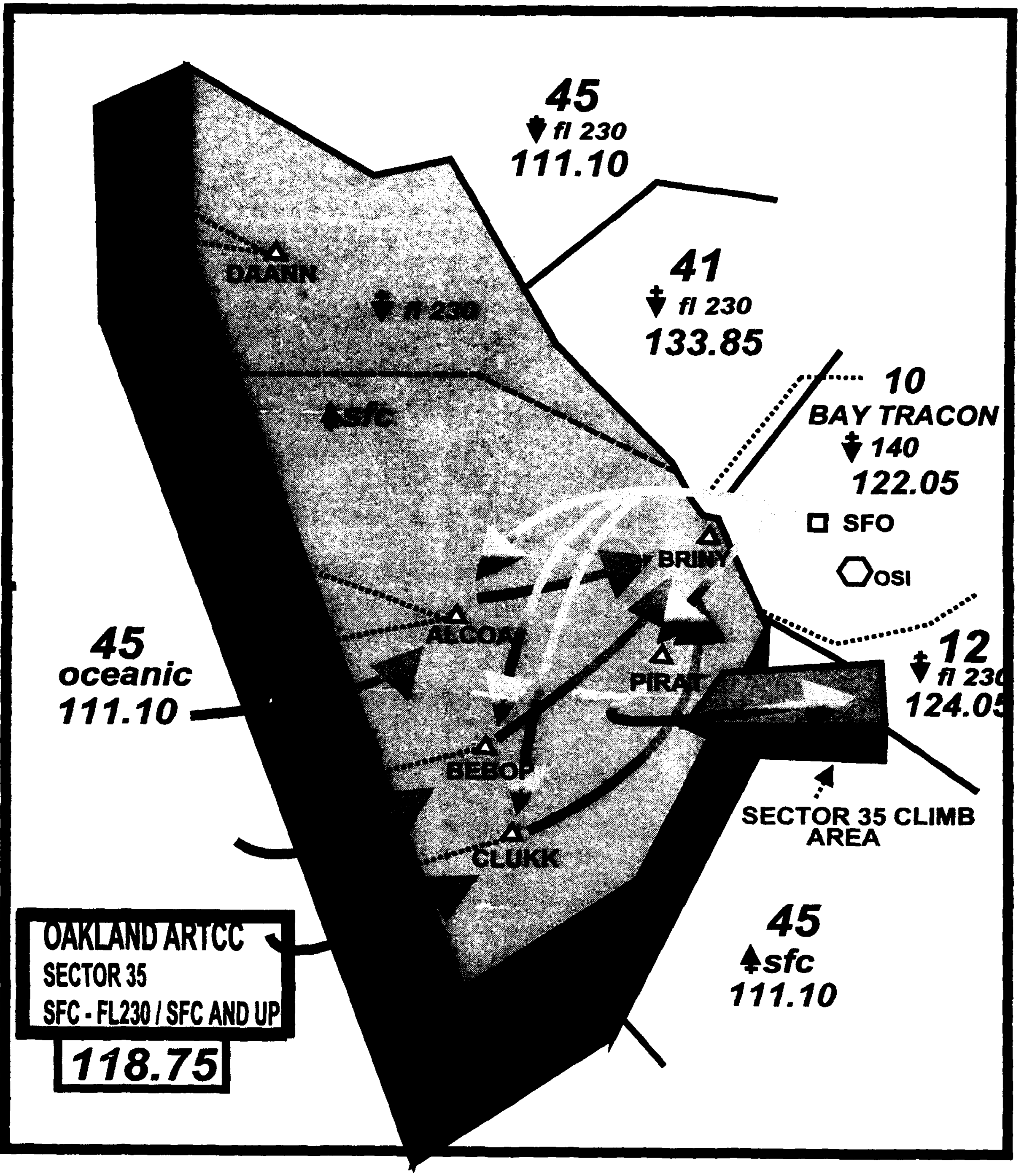
Operation of Equipment
- Equipment Preparation
- Radar Settings

Control Procedures
- Speed Restrictions
- Vectoring
- Sequencing
- Arrival Procedures
- Departure Procedures
- Point-out Procedures
- Holding

Flight Plan Information
- Sequencing Flight Progress Strips
- Non-Radar Oceanic Coordination
- Altitude Coordination

ASSIGNMENT OF AIRSPACE

Except for BAY TRACON airspace, Sector 35 has jurisdiction within the boundaries depicted, at FL230 and BELOW, and SURFACE and UP.



EQUIPMENT PREPARATION

Video maps available to Sector 35:

MAP 1 - Navaids and Intersections

MAP 2 - Airways and Sector Boundaries

MAP 3 - High Altitude Sector Boundaries

MAP 4 - Special Areas

RADAR SETTINGS

RANGE:	250 miles
FILTER KEYS SELECTED:	WX1, WX2, STROBE, MAP1, MAP2, FDB, ALL PRIMARIES, SEL BCN, NON MODE C, ALT1 through ALT8.
	(Other keys optional)
ALTIMETER SETTINGS:	SFO

MANDATORY SPEED RESTRICTIONS

BAY TRACON ARRIVALS:

Jets shall cross 20 miles southwest of OSI VORTAC (BRINY INTERSECTION) at 8,000 feet and 250 knots.

* OSI = WOODSIDE VORTAC

SEQUENCING

Sequence oceanic arrivals cleared to BAY TRACON via BRINY..OSI..SFO

ARRIVAL PROCEDURES

BAY TRACON AIRPORTS:

JET ARRIVALS

cleared via:

ALCOA..BRINY..OSI..SFO
or
CLUKK..BRINY..OSI..SFO
or
BEBOP..BRINY..OSI..SFO

and cross:

BRINY INTERSECTION

at:

8,000 FEET
and
250 KNOTS

* ENI = MENDOCINO VORTAC
PYE = POINT REYES VORTAC

DEPARTURE PROCEDURES

BAY TRACON AIRPORTS:

JETS are cleared as filed, climbing to 10,000 feet. Oakland ARTCC has control for turns and speed.

PROPS are cleared to 10,000 feet, or requested lower altitude, and are **not** sector 35's control for climb.

When traffic does not permit a climb to requested altitude, climb the aircraft to the highest available altitude in your airspace, and execute a hand-off to the adjoining sector. (see **Altitude Coord.**)

POINT OUT PROCEDURES

Whether or not the handoff has been accepted, the transferring controller shall make all necessary point outs within the same altitude stratum (low to low or high to high) unless otherwise coordinated.

HOLDING

RAINS (published)

Hold SW of RAINS (OAK219059) on the OAK 219 radial.
Right turns
Standard leg
Min. altitude 14,000 feet
Max. altitude FL450

* OAK = OAKLAND VORTAC

NONRADAR/OCEANIC COORDINATION

The next sector/facility will have all necessary information on nonradar/oceanic flights. Acceptance of track control shall constitute approval to enter the next sector's or facility's airspace.

ALTITUDE COORDINATION

Acceptance of a hand-off by the next center sector, of an aircraft with a temporary altitude in the data block, shall constitute approval of that altitude.

ENI = Mendocino VORTAC
PYE = Point Reyes VORTAC
OAK = Oakland VORTAC
MQO = Morrow Bay VORTAC
OSI = Woodside VORTAC

OAKLAND CENTER

SECTOR 40/41

STANDARD OPERATING PROCEDURES

Assignment of Airspace
- Sector Boundaries
- Sector Graphic Chart

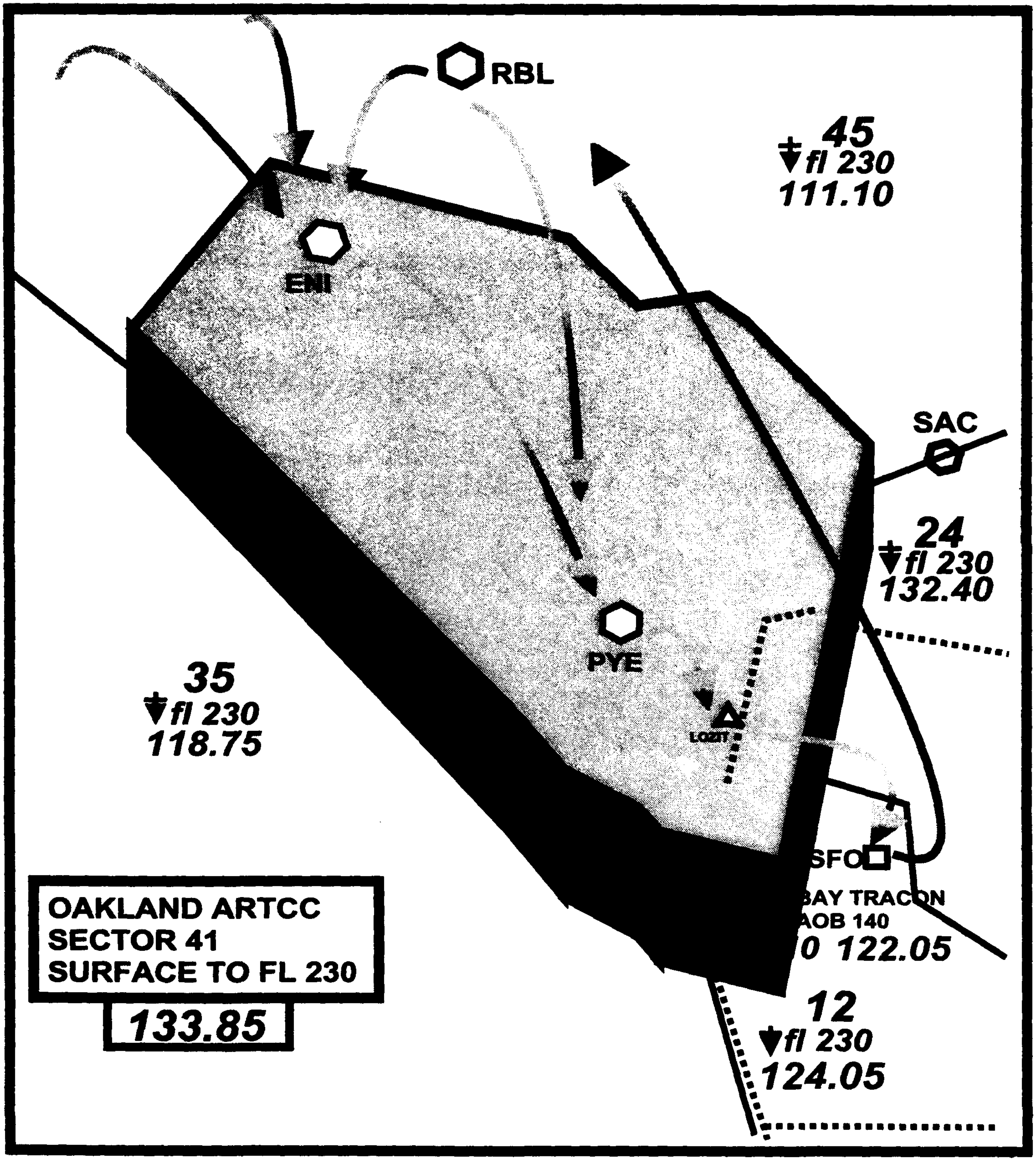
Operation of Equipment
- Equipment Preparation
- Radar Settings

Control Procedures
- Speed Restrictions
- Vectoring
- Sequencing
- Arrival Procedures
- Departure Procedures
- Point-out Procedures
- Holding

Flight Plan Information
- Sequencing Flight Progress Strips
- Non-Radar Oceanic Coordination

ASSIGNMENT OF AIRSPACE

Except for BAY TRACON airspac, Sector 41 has jurisdiction within the boundaries depicted, at FL230 and BELOW.



EQUIPMENT PREPARATION

Video maps available to Sector 40/41:

MAP 1 - Navaids and Intersections

MAP 2 - Airways and Sector Boundaries

MAP 3 - High Altitude Sector Boundaries

MAP 4 - Special Areas

MAP 5 - E-MSAW

RADAR SETTINGS

RANGE: 60 miles (centered 5 NW of STS VOR)

FILTER KEYS SELECTED: WX1, WX2, STROBE, MAP1, MAP2, FDB, ALL PRIMARIES, SEL BCN, NON MODE C, ALT1 through ALT5.
(other filter keys optional)

ALTIMITER SETTINGS: SFO, OAK

ALTITUDE LIMITS: 000B242

MANDATORY SPEED RESTRICTIONS

BAY TRACON ARRIVALS:

Jets shall cross **LOZIT INTERSECTION** (22 miles NW of SFO) at 11,000 feet and 250 knots.

SEQUENCING

Sequence BAY TRACON arrivals from the north cleared to BAY TRACON via PYE..LOZIT..SFO. Aircraft operating above FL240 shall be assigned FL240 by the previous sector.

* ENI = MENDOCINO VORTAC
PYE = POINT REYES VORTAC

ARRIVAL PROCEDURES

BAY TRACON AIRPORTS:

JET ARRIVALS

cleared via:

PYE..LOZIT..SFO

and cross:

LOZIT INTERSECTION
(22 MILES NW of SFO)

at:

11,000 feet
and
250 knots

PROP ARRIVALS

cleared via:

PYE..LOZIT..SFO

and cross:

LOZIT INTERSECTION

at:

9,000 feet
or
7,000 feet

NOTE: High performance turboprops (E120,SW3, etc.) may be cleared via the jet procedures at controller's discretion.

* PYE = POINT REYES

DEPARTURE PROCEDURES

BAY TRACON AIRPORTS:

JETS are cleared as filed, climbing to FL230, or lower altitude if requested. Oakland ARTCC has control for turns and speed.

PROPS are cleared to 10,000 feet, or lower altitude if requested, and are Oakland ARTCC's control for climb.

When traffic permits, a temporary altitude of FL230 should be entered into the data-block of all aircraft requesting FL240 or above, and a hand-off should be made to the overlying sector. (see **Altitude Coord.**)

When traffic does not permit a climb to FL230, climb the aircraft to the highest available altitude in your airspace, and execute a hand-off to the adjoining sector.

POINT OUT PROCEDURES

Whether or not the handoff has been accepted, the transferring controller shall make all necessary point outs within the same altitude stratum (low to low or high to high) unless otherwise coordinated.

HOLDING

PYE (published)

Hold NW of PYE on the PYE 325 radial.
Right turns
Standard leg
Min. altitude 5,000 feet
Max. altitude FL450.

* PYE = POINT REYES VORTAC

FLIGHT PLAN INFORMATION

SEQUENCING FLIGHT PROGRESS STRIPS

3 Suggested Bayheaders:

ACTIVE:	Used for active flight plans.
PROPOSAL:	Proposal bay for all departures or pop-ups.
SECTOR 41:	Bay for pending strips.

NONRADAR/OCEANIC COORDINATION

The next sector/facility will have all necessary information on nonradar/oceanic flights. Acceptance of track control shall constitute approval to enter the next sector's or facility's airspace.

ALTITUDE COORDINATION

Acceptance of a hand-off by the next center sector, of an aircraft with a temporary altitude in the data block, shall constitute approval of that altitude.

ENI = Mendocino
PYE = Point Reyes
SGD = Scaggs Island
SAU = Sausalito
OAK = Oakland
SAC = Sacramento
RBL = Red Bluff
SFO = San Francisco

APPENDIX C

DATA COLLECTION MATERIALS

ISSS PROTOTYPE EVALUATION

NAME: ____

Briefly describe your exposure to, or experience with, the ISSS common console prior to this study:

QUESTIONNAIRE INSTRUCTIONS:

The ISSS common console prototype that is being used in this study was assembled to provide a simulation environment in which Data Link ATC services could be developed and tested. It is not intended to be an exact copy of the real common console or to emulate all of the functionality of the actual ISSS system. However, in order to serve as a valid test bed for evaluations, it must faithfully reproduce those aspects of the common console and of the ISSS controller's task that could affect a controller's Data Link performance or the judgments he or she would be asked to make about Data Link during a simulation.

This questionnaire is aimed at getting your inputs regarding those characteristics of the prototype system that may need to be modified or improved in order to optimally support Data Link development and testing.

Please answer the following questions based on your best professional judgement, regardless of the level of experience that you have had with actual ISSS software and equipment.

Remember, you are evaluating the ability of the prototype to support Data Link testing in the ISSS environment, <u>not</u> necessarily its ability to perfectly simulate all ISSS capabilities.

1. Do you feel that the prototype <u>hardware</u> (e.g. console design, keyboard, trackball, display surface, audio communications system) is sufficiently realistic to support Data Link development and testing?

YES _____

NO _____

If no, please explain:

2. Are the appearances of the screen graphics and text sufficiently realistic to support Data Link development and testing?

YES ______

NO ______

If no, please explain:

3. Are the dynamic aspects of the simulation sufficiently realistic in terms of system response time and aircraft movement?

YES ______

NO ______

If no, please explain:

4. Does the prototype currently support a sufficient number of views, functions and command inputs of the ISSS common console to permit realistic testing of Data Link?

YES ______

NO ______

If no, please explain:

5. What other specific changes to the prototype hardware or software are needed to adequately support Data Link evaluation?

REVIEWER'S NAME ______________________________

CONTROLLER EVALUATION
INITIAL DATA LINK EN ROUTE SERVICES

ISSS COMMON CONSOLE

DESIGN REVIEW BOOKLET

INSTRUCTIONS

This booklet contains a series of simulation exercises and questions which will permit you to independently review and evaluate the designs of the candidate ISSS services. The goal of this review is to identify those aspects of the designs which are acceptable as presented and those which will require modification.

The booklet contains six sections which address individual design features or services. Each section corresponds to one of the sections in the DESIGN DESCRIPTION BOOKLET.

You should begin your review of each section by carefully reading the DESIGN DESCRIPTION. Next, working with your partner, complete the SCRIPTED EXERCISE FRAME in this booklet that is associated with the description. Finally, working on your own, answer all questions for the section and record any recommendations for design changes. Explain your reasons for suggesting these changes.

Be sure to read the DESIGN DESCRIPTION for a section before entering the command to start the next scripted exercise frame on the prototype common console.

Remember, your main task is to concentrate on completing the evaluation booklet. We are doing the review in the ISSS prototype laboratory so that you can examine the service designs as you work on the booklet. The exercises are designed to permit each pair of controllers to work at their own pace. During this session, it is not important to maintain precise control of the simulated air traffic.

NOTE: All exercise scenarios occur in Sector 41 of the Oakland airspace. We suggest that you set the range on the ISSS common console to 150 miles for best viewing of the displays.

EXERCISE FRAME 1

STATUS LIST, DATA BLOCK DISPLAY AND ENTRY ERROR MESSAGES

Read the entire Full Data Block, Status List and Entry Error description.

Then, select Frame 1 from the menu to start this exercise.

Frame Overview:

This frame is a static representation of the situation display. It presents a sample status list and several data blocks to illustrate status list format and indicator abbreviations, Data Link symbology, and basic move and suppress commands.

Complete the Following Exercises:

1. Observe Full Data Block Equipage and Eligibility Symbols

    AA5621 - No symbol: not equipped for Data Link communication

    UAL666 - Open diamond: equipped for Data Link communication, but this sector not eligible

    Other aircraft in sector - Filled diamond: equipped for Data Link communication and this sector is eligible

2. Observe Service Abbreviations, Message Content and Status Indicators in Status List (and FDB)

USA200 - You have uplinked an assigned altitude of 11,000 ft. and message is in the sent state as shown by the status list abbreviation SNT and the timesharing display in the second line of the FDB.

SWA283 - You have uplinked an interim altitude of 7000 ft. and the pilot has responded UNABLE as shown by the status list and FDB abbreviation UNB in yellow.

USA 561 - You have uplinked menu text item A and the pilot has responded STANDBY as shown by the status list and FDB abbreviation STB in yellow.

DAL1321 - You have handed this aircraft off to another sector with transfer of communication in the manual mode. The system has prepared a TOC message for uplink as shown by the HLD (held) abbreviation in the status list.

UAL162 - You have sent a backup comunications message "CALL COMPANY" and the pilot has responded Wilco.

AA776 - You uplinked an assigned altitude of 11,000 ft. and the pilot has failed to respond within 40 seconds as shown by the status list and FDB displays of TIM (Time Out).

3. Move the status list to another position on the situation display.

4. Suppress the status list and retrieve it back to the situation display.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet, then turn to the next service description.

STATUS LIST, DATA BLOCK AND INPUT ERROR MESSAGE REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the Status List that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. Do you feel that the Status List in addition to the FDB will be necessary for operational implementation? Why or why not?

3. Do the abbreviated status messages (SNT, HLD, WIL etc.) and yellow alert codes used in the Status List provide sufficient information? Are they easy to interpret?

4. Are the abbreviations for the services (TC, AA, IA, MT, FT) used in the Status List adequate?

5. Are the data block filled and open diamond symbols used to indicate Data Link equipage and eligibility easy to interpret? Do you foresee any problems in discriminating them from one another or from other symbology on the display?

6. Are the inputs used to move and suppress/recover the Status List appropriate and easy to perform?

7. Do you feel that the Data Link entry error messages presented in the description will provide adequate feedback about the source of input errors?

8. What should be done to improve the design of the Status List, FDB displays and entry error messages <u>as implemented</u> in the prototype? Include any changes suggested by your answers to questions 2.- 7. above.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, <u>BUT</u> THE FOLLOWING WOULD BE DESIRABLE: (describe)

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES <u>MUST</u> BE MADE:

EXERCISE FRAME 2
TRANSFER OF COMMUNICATION

Read the entire transfer of communication service description. Then, select Frame 2 from the menu to start this exercise.

Frame Overview:

This frame is designed to permit you to focus on sending the TOC service to aircraft departing the sector. Aircraft in this scenario will approach the boundary and exit your sector.

Complete the Following Exercises:

1. Send Automatic TOC

- Set TOC mode to automatic

- Handoff several aircraft and observe FDB and Status List displays change as handoff is accepted, TOC is uplinked, and pilot wilcoes message.

2. Observe TOC Failures

- Keep TOC mode in automatic

- Tell simulation pilot to return an UNABLE response to the TOC message you will be sending to an identified aircraft.

- Handoff the aircraft, observe unable displays in FDB and Status list, and maintenance of eligibility at your sector.

- Close transaction by deleting displays.

- Repeat above sequence with another aircraft requesting the simulation pilot to allow message to TIME OUT.

3. Send Manual TOC

- Set TOC mode to Manual.

- Handoff several aircraft. Note HELD messages in Status List when handoffs are accepted. Observe FDB and Status List displays when you uplink held messages, and when pilot wilcoes message.

4. Send an Automatic TOC from Manual Mode

- Keep TOC mode in Manual.

- Handoff several aircraft, adding the "S" to some handoff commands to automatically send the TOC message.

5. Force and Steal Eligibility

- Force Data Link eligibility for several aircraft to another sector without a handoff. Send the new frequency to the aircraft by voice.

- Force Data Link eligibility for a second group of aircraft to another sector without a handoff. Send the new frequency by Data Link by adding the "S" to the force command.

- Steal track control and Data Link eligibility for several aircraft that you have already handed off and transferred to a new sector. Include the "S" in the steal command to send your frequency to the aircraft.

- Steal Data Link eligibility for several aircraft that you have already handed off and transferred to a new sector and simultaneously force it to another sector. Include the "S" in the command to send the new frequency to the aircraft.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet, then turn to the next service description.

TRANSFER OF COMMUNICATION REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the TOC service that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. Is the up-arrow in the data block an effective way to indicate that a TOC message has been sent and that Data Link eligibility is changing?

3. Is a display of the currently active TOC mode (AUTO/MANUAL) needed?

4. Is the reversion of the Data block eligibility/equipage symbol from an up-arrow to a yellow filled diamond adequate for notifying the controller that the pilot has failed to respond quickly enough (Time Out) or that an Unable response has been received?

5. Are the inputs for "stealing" and "forcing" Data Link eligibility logical and appropriate?

6. What should be done to improve the design of the TOC service as implemented in the ISSS prototype? Include any changes suggested by your answers to questions 2 - 5.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, BUT THE FOLLOWING WOULD BE DESIRABLE: (describe)

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES MUST BE MADE:

EXERCISE FRAME 3

ALTITUDE ASSIGNMENT - MANUAL ENTRY

Read the entire altitude assignment description.
Then, select Frame 3 from the menu to start this exercise.

Frame Overview:

This frame is designed to permit you to focus on sending Altitude Assignments using the manual entry procedure. Aircraft in this scenario will be moving through your sector, and you will not be required to accept or offer handoffs.

Complete the Following Exercises:

1. Send Altitude Messages

- Send Altitude Assignments to several aircraft using both keyboard and trackball methods of entering FLIDs.

- Observe FDB and Status List indicators of message content and changes in status as message is sent and wilcoed.

- Repeat the above steps for several new aircraft sending Interim Altitudes.

2. Observe "Failed" Messages

- Identify several aircraft to the simulation pilot and tell him to respond UNABLE.

- Observe Unable displays in FDB and Status List.

- Close transaction and clear displays with delete command.

- Repeat above steps requesting a TIME OUT from simulation pilot.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet, then turn to the next service description.

ALTITUDE ASSIGNMENT - MANUAL ENTRY REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the Altitude Assignment service that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. Are the inputs used to send altitude assignments and interim altitudes appropriate?

3. Does the timesharing data block altitude display followed by "S" provide useful and adequate feedback for indicating the Sent status and content of an altitude message?

4. Are the Unable and Time Out displays in the data block adequate for alerting the controller? Are the procedures used to delete these displays and close the transaction appropriate?

5. Do you foresee any significant possibility that controllers will make undetected errors when uplinking altitudes using this service? If yes, please explain.

6. What should be done to improve the design of the Altitude Assignment service <u>as implemented</u> on the ISSS prototype? Include any changes suggested by your answers to questions 2. - 5.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, BUT THE FOLLOWING WOULD BE DESIRABLE: (describe)

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES MUST BE MADE:

EXERCISE FRAME 4

INITIAL CONTACT

Read the entire Initial Contact service description.
Then, select Frame 4 from the menu to start this exercise.

Frame Overview:

This frame is designed to permit you to focus on processing the Initial Contact (IC) from aircraft entering the sector. Aircraft in this scenario will approach the boundary and enter your sector. You will accept the offered handoffs and respond to IC failures.

Complete the Following Exercises:

BE SURE TO LOG ON TO THE COMMON CONSOLE BEFORE BEGINNING THESE EXERCISES!

1. Observe Normal Initial Contact Procedure

- Accept handoffs for several aircraft.

- Observe the transfer of Data Link eligibility to your sector in the FDB. Note that the IC is transparent -- no display indications when correct assigned altitude is downlinked with the TOC wilco.

2. Process Aircraft Failure to Report

- Identify several aircraft being handed off to your sector to the simulation pilot and tell him not to append his assigned altitude when wilcoing the TOCs.

- Observe "NALT" display in FDB.

- Clear the NALT using the delete command for some aircraft, and by updating the assigned altitude or uplinking an assigned altitude for others.

3. Process a Discrepancy in Reported and Flight Plan Altitudes

- Identify several aircraft being handed off to your sector to the simulation pilot and tell him to send an erroneous altitude with his wilco to the TOCs.

- Observe the error display in the FDB.

- Clear the error using the delete command for some aircraft, and by updating the assigned altitude or uplinking an assigned altitude for others.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet, then turn to the next service description.

INITIAL CONTACT REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the IC service that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. Is the yellow "NALT" display in the data block adequate to capture the controller's attention when the flight deck fails to downlink a reported assigned altitude with the wilco to the TOC?

3. Are the timesharing altitude report and the flight plan altitudes followed by a yellow "E" in the data block display adequate to capture the controller's attention when there is a discrepancy?

4. Are the two procedures for clearing the "NALT" and altitude discrepancy displays appropriate and adequate? (i.e. slewing to the FDB or updating altitude)

5. What should be done to improve the design of the IC service <u>as implemented</u> in the ISSS prototype? Include any changes suggested by your answers to questions 2 - 4.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, <u>BUT</u> THE FOLLOWING WOULD BE DESIRABLE:

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES <u>MUST</u> BE MADE:

EXERCISE FRAME 5
MENU TEXT

Read the entire Menu Text service description.
Then, select Frame 5 from the menu to start this exercise.

<u>Frame Overview</u>:

This frame is designed to permit you to focus on sending uplinks from the menu and on inputs used to control and modify the menu. Aircraft in this scenario will be moving through your sector, and you will not be required to accept or offer handoffs.

<u>Complete the Following Exercises:</u>

1. Send Altitude Messages from the Menu

- Send several altitude assignment and interim altitude messages by menu selection -- try both trackball and keyboard entry methods.

- Observe FDB and Status List message content displays and status changes.

2. Send Text Messages from the Menu

- Send several text messages from the menu -- try both trackball and keyboard entry methods.

- Observe FDB and Status List message content displays and status changes.

- Identify an aircraft and tell the simulation pilot to respond UNABLE to a text message from the menu.

- Observe unable message provided in status list only.

3. Temporary and Permanent Modifications to an Altitude Menu Item
- Select an altitude item, make a one-time modification to the altitude value and send the message.

- Observe the FDB and Status list displays for the new uplinked value.

- Note that no change is made in the displayed menu item.

- Select another altitude item and make a permanent change to the altitude value.

- Observe change in displayed menu.

- Return value to adapted value using menu default command

4. Control Menu

- Move the menu to a new location on the situation display.

- Suppress the menu and retrieve it back to the display.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet, then turn to the next service description.

MENU TEXT REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the Menu Text function that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. For altitude items, the menu includes an indicator identifying those items that are interim altitudes (QQ) and those that are assigned altitudes (QZ). Are these necessary? If so, should QQ and QZ, or some other indicators, be used (e.g. IA and AA).

3. When a text message is uplinked from the menu, no data block display of message type and transaction status is provided. Is a data block display needed?

4. The status list identifies message content using the menu item identifier (e.g. MT A). Does this provide sufficient feedback about the message that was sent?

5. Do you foresee any significant possibility that controllers will make undetected errors when uplinking altitudes using the menu function? If yes, please explain.

6. What should be done to improve the design of the Menu Text function as implemented in the ISSS prototype? Include any changes suggested by your answers to questions 2 - 5.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, BUT THE FOLLOWING WOULD BE DESIRABLE: (describe)

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES MUST BE MADE:

EXERCISE FRAME 6

COMMUNICATIONS BACKUP

Read the entire Communications Backup service description.
Then, select Frame 6 from the menu to start this exercise.

Frame Overview:

This frame is designed to permit you to focus on composing and sending messages using the communications backup service. Aircraft in this scenario will be moving through your sector, and you will not be required to accept or offer handoffs.

Complete the Following Exercises:

1. Send Communications Backup Message

- Compose and send sveral communications backup messages.

- Observe content and status information provided in Status List only.

When you have completed this exercise, type "EXIT" to end the exercise frame. Individually answer all questions in this section of the review booklet.

COMMUNICATIONS BACKUP REVIEW QUESTIONS:

1. Does the description accurately represent the design and operation of the Communications Backup service that you examined on the ISSS prototype?

_____ YES, THE DESCRIPTION IS CORRECT

_____ NO, IT DOESN'T MATCH

Describe those aspects of the description that did not match your observations --

2. No data block display of message content or transaction status are provided for communications backup. Are these needed or are the Status list displays sufficient?

3. Is the truncated version of the message provided in the status list an adequate indication of the message's content?

4. What should be done to improve the design of the Communications Backup service as implemented in the ISSS prototype? Include any changes suggested by your answer to questions 2 and 3.

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE DESIRABLE OR NEEDED

_____ THE CURRENT IMPLEMENTATION IS ACCEPTABLE -- NO CHANGES ARE NEEDED, BUT THE FOLLOWING WOULD BE DESIRABLE: (describe)

_____ THE CURRENT IMPLEMENTATION IS UNACCEPTABLE -- THE FOLLOWING CHANGES <u>MUST</u> BE MADE:

SWAT WORKLOAD RATINGS

After each test run, you will be asked to complete a rating of the workload that you actually experienced while controlling traffic. The scale that you will use to make these estimates is known as SWAT (Subjective Workload Assessment Technique). SWAT was developed as a method for collecting quantified subjective data on how hard a person feels he or she had to work when performing different tasks or when using different procedures and equipment to perform duties.

If you examine the SWAT rating scale, you will notice that SWAT defines workload in terms of a combination of three different dimensions that contribute to the subjective feeling of "working hard". A workload rating in SWAT is accomplished by selecting a "1", "2" or "3" on EACH of the three scales representing the dimensions of TIME LOAD, MENTAL EFFORT, and PSYCHOLOGICAL STRESS.

Each of these dimensions and their levels are described below:

<u>TIME LOAD</u>

Time Load refers to the fraction of the total time that you are busy. When Time Load is low, sufficient time is available to complete all of your mental work with some time to spare. As Time Load increases, spare time drops out and some aspects of performance overlap and interrupt one another. This overlap and interruption can come from performing more than one task or from different aspects of performing the same task. At high levels of Time Load, many things occur simultaneously, you are busy, and interruptions are very frequent.

Time Load is rated on the three point scale below:

(1) Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

(2) Occasionally have spare time. Interruptions or overlap among activities occur frequently.

(3) Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

MENTAL EFFORT LOAD

As described above, Time Load refers to the amount of time one has available to perform a task or tasks. In contrast, Mental Effort Load is an index of the amount of attention or mental effort required, regardless of the number of tasks to be performed or any time limitations. When Mental Effort Load is low, the concentration and attention required by a task is minimal and performance is nearly automatic. As the demand for mental effort increases due to task complexity or the amount of information which must be dealt with in order to perform adequately, the degree of concentration and attention required increases. High Mental Effort Load demands total attention or concentration due to task complexity or the amount of information that must be processed.

Mental Effort Load is rated using the three point scale below:

(1) Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.

(2) Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

(3) Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD

Psychological Stress Load refers to the contribution to total workload of any conditions that produce anxiety, frustration, or confusion while performing a task or tasks. At low levels of stress, one feels relatively relaxed. As stress increases, confusion, anxiety, or frustration increase and greater concentration and determination are required to maintain control of the situation.

Psychological Stress Load may be rated on the three point scale below:

(1) Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.

(2) Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.

(3) High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Each of the three dimensions just described contribute to workload during performance of a task or group of tasks. Note that although all three factors may be correlated, they need not be. For example, one can have many tasks to perform in the time available (high Time Load) but the tasks may require little concentration (low Mental Effort Load). Likewise, one can be anxious and frustrated (high Stress Load) and have plenty of spare time between relatively simple tasks. Since the three dimensions contributing to workload are not necessarily correlated, please treat each dimension individually and give independent assessments of the Time Load, Mental Effort Load, and Psychological Stress Load that you experienced during each test run.

The form that you will be using to make your SWAT ratings during the Data Link test sessions is shown on an attached page. Note that the descriptions for each level of time, effort and stress load have been removed to save space. Should you need to review these descriptions during testing, a copy of the full scale will be available at all times.

SWAT SCALE DEVELOPMENT CARD SORT

Now that you are familiar with the SWAT rating scale, there is one last procedure that must be completed before testing can begin. This procedure is a card sorting task that will allow us to interpret your SWAT workload ratings.

One of the most important features of SWAT is its unique scoring system. The developers of SWAT recognized that different people have different conceptions of how the time, effort and stress dimensions combine to produce an overall impression of low and high workload. Because of these differences, a special card sorting procedure is used in SWAT to define a distinctive workload scale for each person. This individualized scale greatly improves our ability to accurately interpret the actual workload ratings that you will be making during the test sessions.

In order to develop your individual scale, we need information from you regarding the amount of workload that you feel is produced by various combinations of the three levels on the time, effort and stress dimensions. We get this information by having a person rank order a set of cards. Each card contains a different combination of the levels of time load, mental effort load, and stress load. Since there are three dimensions, and each dimension has three levels, there are 27 cards in the deck that you will be sorting. Your job will be to sort the cards so that they are ranked according to the level of workload represented by each card. Thus, the first card in the deck will represent the lowest workload and the last card will represent the highest workload.

In completing your card sorts, please consider the workload imposed on a person by the combination represented in each card. Arrange the cards from the lowest workload condition through the highest condition. You may use any strategy you choose in rank ordering the cards.

One strategy that proves useful is to arrange the cards into a number of preliminary stacks representing "High", "Moderate", and "Low" workload. Individual cards can be exchanged between stacks, if necessary, and then rank ordered within stacks. Stacks can then be recombined and checked to be sure that they represent your ranking of lowest to highest workload. However, the choice of strategy is up to you and you should choose the one that works best for you.

There is no "school solution" to this problem. There is no correct order. The correct order is what, in your judgment best describes the progression of workload from lowest to highest for a general case rather than any specific event. That judgment differs for each of us. The letters you see on the back of the cards are to allow us to arrange the cards in a previously randomized sequence so that everyone gets the same order. If you examine your deck you will see the order on the back runs from A through Z and then ZZ.

Please remember:

(1) The card sort is being done so that a workload scale may be developed for you. This scale will have a distinct workload value for each possible combination of Time Load, Mental Effort Load, and Psychological Stress Load. The following example demonstrates the relationship between the card sort and the resulting workload scale:

TIME	EFFORT	STRESS		WORKLOAD SCALE
1	1	1	------------	0.0
.	.	.	.	
.	.	.	.	
.	.	.	.	
.	.	.	.	
3	3	3	-----------	100.0

Note that other than the fact that a 1-1-1 will always represent the lowest workload and that a 3-3-3 will always represent the highest workload, the remaining cards could occur in a number of orders. Your order will depend on how you weight the importance of Time, Effort and Stress dimensions.

(2) When performing the card sorts, use the descriptors printed on the cards. Please remember <u>not</u> to sort the cards based on one particular task. Sort the cards according to your general view of workload and how important you consider the dimensions of Time, Mental Effort, and Psychological Stress Load to be when you think of high and low workload experiences.

(3) A SWAT rating for any situation consists of one number from each of the three dimensions. For example, a possible SWAT rating is 1-2-2. This represents a 1 for Time Load, a 2 for Mental Effort Load, and a 2 for Psychological Stress Load.

(4) We are not asking for your preference concerning Time, Mental Effort, and Psychological Stress Load. Some people may prefer to be "busy" rather than "idle" in either Time Load, Mental Effort Load, or Psychological Stress Load dimension. We are not concerned with this preference. We need information on how the three dimensions and the three levels of each one will affect the level of workload as you see it. You may prefer a 2-1-1 situation instead of a 1-1-1 situation. However, you should still realize that the 1-1-1 situation imposes less workload on you and leaves a greater reserve capacity.

The sorting will probably take 30 minutes to an hour. Please feel free to ask questions at any time.

SWAT WORKLOAD

TEST RUN ____________ **POSITION** ____________

DL / VOICE ____________ **PVD / ISSS** ____________

Rate the workload that you *actually experienced* while controlling traffic during the test run just completed. For each of the SWAT dimensions of TIME LOAD, EFFORT and STRESS, place an "X" on the appropriate line to indicate the level that you experienced ranging from 1 (low) to 3 (high)

	1	2	3
TIME LOAD	______	______	______
MENTAL EFFORT	______	______	______
STRESS	______	______	______

Please describe any events or experiences that may have affected your workload during this test run:

SWAT WORKLOAD RATING FORM

RATER NAME ______________________________________

CONTROLLER EVALUATION

DATA LINK ISSS SERVICES

FINAL RATINGS

The forms in this booklet should be completed after you have finished all four test runs of the full scale simulation.

Their are two sets of rating forms. The first set will ask you to make some projective estimates of the way in which Data Link will affect the controller and the ATC system in an actual operational implementation.

The second set of ratings will allow you to make some overall quantitative judgments about each of the ISSS Data Link services as they have been implemented for this study.

Please read the instructions preceding each set of ratings carefully before completing the rating scales.

PART 1: PROJECTIVE COMPARISONS

In the following three questions you will be asked to use your simulation experiences to make some projective judgements about how you think Data Link and the features of existing and future workstations would affect the controller and the ATC system in an actual operational implementation.

To do this, you will make all possible comparisons of the four combinations of communication system and controller workstation that were used in the simulation runs. These comparisons will be made on four dimensions: controller workload, ATC system safety, ATC system capacity, and controller efficiency/productivity.

For each dimension, the six possible pairs are presented on opposite ends of a line of spaces. For each pair, place an "X" in the space which best describes your view of which of the two combinations of communication system and workstation is higher on the dimension being addressed. If the pair does not differ, place the "X" in the "Equal" space.

Remember, other than the current Host/PVD system with voice communication with which you have direct operational experience, you are making projective judgments about the effects of these combinations in a future operational setting. Thus, you should assume normal operational levels of controller training and airspace familiarity.

The following abbreviations are used to specify the four combinations on the comparison scales:

PVD/V - Host/PVD system, Voice-only communications

PVD/V&D - Host/PVD system, Voice and Data Link communications

ISSS/V - ISSS system, Voice-only communications

ISSS/V&D - ISSS system, Voice and Data Link communications

1) Compare each of the following pairs of workstation and communication conditions in terms of the way in which you feel they currently impact, or will impact, CONTROLLER WORKLOAD in an operational implementation.

	<--Higher Workload			Higher Workload-->		
	Much Higher	Somewhat Higher	Equal	Somewhat Higher	Much Higher	
PVD/V	____	____	____	____	____	ISSS/V
PVD/V	____	____	____	____	____	PVD/V&D
PVD/V	____	____	____	____	____	ISSS/V&D
ISSS/V	____	____	____	____	____	PVD/V&D
ISSS/V	____	____	____	____	____	ISSS/V&D
PVD/V&D	____	____	____	____	____	ISSS/V&D

2) Compare each of the following pairs of workstation and communication conditions in terms of the way in which you feel they currently impact, or will impact, ATC SYSTEM CAPACITY in an operational implementation.

	<--Higher Capacity			Higher Capacity-->		
	Much Higher	Somewhat Higher	Equal	Somewhat Higher	Much Higher	
PVD/V	____	____	____	____	____	ISSS/V
PVD/V	____	____	____	____	____	PVD/V&D
PVD/V	____	____	____	____	____	ISSS/V&D
ISSS/V	____	____	____	____	____	PVD/V&D
ISSS/V	____	____	____	____	____	ISSS/V&D
PVD/V&D	____	____	____	____	____	ISSS/V&D

3) Compare each of the following pairs of workstation and communication conditions in terms of the way in which you feel they currently impact, or will impact, <u>ATC SYSTEM SAFETY</u> in an operational implementation.

	<--Higher Safety			Higher Safety-->		
	Much Higher	Somewhat Higher	Equal	Somewhat Higher	Much Higher	
PVD/V	____	____	____	____	____	ISSS/V
PVD/V	____	____	____	____	____	PVD/V&D
PVD/V	____	____	____	____	____	ISSS/V&D
ISSS/V	____	____	____	____	____	PVD/V&D
ISSS/V	____	____	____	____	____	ISSS/V&D
PVD/V&D	____	____	____	____	____	ISSS/V&

4) Compare each of the following pairs of workstation and communication conditions in terms of the way in which you feel they currently impact, or will impact, <u>CONTROLLER EFFICIENCY/PRODUCTIVITY</u> in an operational implementation.

	<--Higher E/P			Higher E/P-->		
	Much Higher	Somewhat Higher	Equal	Somewhat Higher	Much Higher	
PVD/V	____	____	____	____	____	ISSS/V
PVD/V	____	____	____	____	____	PVD/V&D
PVD/V	____	____	____	____	____	ISSS/V&D
ISSS/V	____	____	____	____	____	PVD/V&D
ISSS/V	____	____	____	____	____	ISSS/V&D
PVD/V&D	____	____	____	____	____	ISSS/V&

PART 2: ISSS CANDIDATE SERVICE EVALUATIONS

Each of the following five forms is dedicated to one of the ISSS Data Link service designs that were tested in this study. Two rating scales are provided on each form to evaluate the services as implemented for this study:

OPERATIONAL EFFECTIVENESS AND SUITABILITY

The first scale on each form asks for a rating of operational effectiveness and suitability. To evaluate this factor, you should consider the degree to which each service implementation could effectively accomplish the task it was designed to perform. Thus, you are deciding whether each design provides all of the functions and capabilities that will be needed to meet operational requirements in a field setting. Follow the instructions on the form when completing the rating scale.

CONTROLLER ACCEPTANCE AND PREFERENCE

The second scale on each form asks for a rating of the acceptability of the service design to controllers. To evaluate this factor, consider the extent to which the displays, inputs and procedures for the service would be usable by field controllers and compatible with their styles of controlling air traffic. Follow the instructions on the form when completing the scale.

PLEASE NOTE:

When making your ratings, remember that operational effectiveness/suitability and controller acceptance/preference should be considered independently. Although the two dimensions may vary together, a service design could provide all the functions needed to meet operational requirements and still be poorly suited to the controller's way of doing his job. Likewise, a design could be easy to use, but have limitations which prevent it from covering all operational situations.

Altitude Assignment

Use the scales below to rate the ISSS service indicated above. On the first scale, check the box if this service is unsuitable for operational use. If the service can meet some, or all operational requirements, check the space below the number that best describes its effectiveness.

OPERATIONAL EFFECTIVENESS / SUITABILITY

Highly Effective ↓			Meets Most Operational Requirements ↓			Minimally Effective ↓	☐
1	2	3	4	5	6	7	↑
___	___	___	___	___	___	___	Not Operationally Suitable

On this scale, regardless of the service's effectiveness, check the box if the way in which the service is designed would be completely unacceptable to controllers. If the service design is acceptable, check the space below the number that best describes your preference for the design.

CONTROLLER ACCEPTANCE / PREFERENCE

Highly Preferred ↓			Moderately Preferred ↓			Acceptable, But Not Preferred ↓	☐
1	2	3	4	5	6	7	↑
___	___	___	___	___	___	___	Completely Unacceptable

Please comment on your ratings on the back of this page.

OPERATIONAL EFFECTIVENESS/SUITABILITY AND CONTROLLER ACCEPTANCE/PREFERENCE RATING FORM

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